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A Description of the Major Commercial Irish Moss *(Chondrus crispus Stackh.)* Beds off Western Prince Edward Island

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ABSTRACT

Pringle, J.D. and R.E. Semple. 1983. A description of the major commercial Irish moss (Chondrus crispus Stackh.) beds off western Prince Edward Island. Can. MS Rep. Fish. Aquat. Sci. 1725: v + 117 p.

Seven commercially important Irish moss (Chondrus crispus) beds off western Prince Edward Island were surveyed to determine the exact location and size of each bed. Depth, biomass (percent of cover), and substrate type were charted every 10 m along parallel transect lines 100 m to 160 m apart. The survey method is described and the relationships among Chondrus biomass, depth, and bottom substrate are discussed. The data were graphed on computer-generated contour maps for comparison purposes.

Key words: Chondrus crispus (Irish moss), biomass, substrate, depth, transects, underwater survey.

RÉSUMÉ

Pringle, J.D. and R.E. Semple. 1983. A description of the major commercial Irish moss (Chondrus crispus Stackh.) beds off western Prince Edward Island. Can. MS Rep. Fish. Aquat. Sci. 1725: v + 117 p.

Les relevés de sept lits commercialement importants de mousse d'Irlande (Chondrus crispus) au large de l'ouest de l'Ile-du-Prince-Edouard ont été effectués en vue de déterminer l'endroit et l'étendue exacts de chaque lit. La profondeur, la biomasse (pourcentage de couverture) et le type de substrat ont été enregistrés à tous les 10 m le long de transects parallèles séparés par des distances de 100 à 160 m. Nous décrivons la méthode de relevé et analysons les relations entre la biomasse

de Chondrus, la profondeur et le substrat. Pour mieux comparer les données, nous les avons portées sur des cartes bathymétriques tracées par ordinateur.

INTRODUCTION

The perennial rhodophyte Chondrus crispus Stackh. (Irish moss) is the basis of a major marine plant fishery in the Canadian Maritime provinces (MacFarlane 1961; French 1971; Pringle 1976). Harvesters off the western shore of Prince Edward Island (Marine Plant Harvesting District 1, hereafter referred to as "District 1") crop more Irish moss per kilometer of shore than elsewhere in the Canadian Maritimes (Pringle unpub. data). The bulk of the harvest is mechanically removed by dragrake (Scarratt 1972; Pringle 1979). MacFarlane[1] (pers. comm.) expressed concern about dragraking as the plants are attached to friable sandstone by perennating, discoid holdfasts (Taylor et al. 1981). The latter is responsible for considerable annual recruitment. Pringle (op. cit.) showed that 33% of the fronds in the commercial harvest had holdfasts attached.

Mean annual landings decreased to approximately 8,000 t in the 1970's from approximately 12,000 t in the mid 1960's; this was thought to be due to a decrease in biomass (Pringle 1981).

Annual landings bottomed out at approximately 6,000 t in 1977 and 1978; this was accompanied by a corresponding decrease in CPUE (Pringle op. cit.). Concern was expressed by industry that recruitment overharvesting in District 1 beds had occurred by the incidental removal of holdfasts. Consequently, the Southern Gulf Marine Plants Advisory Committee deemed it important to determine the extent to which areas of substrate, suitable for Irish moss cover, were devoid of Irish moss in the major beds. Also, to determine optimum harvesting strategy for this district and to monitor change in bed characteristics with time, both the exact location and size of each bed were required.

Reported below are the results of a study undertaken to determine the percent cover of Irish moss in relation to both substrate type and water depth in seven (Fig. 1)[2] major commercial beds [chosen, based on annual harvesting effort (Pringle unpub. data) calculated for all beds in the district during the 1975 to 1978 seasons; the beds not assessed contributed little to the mean annual landings during this period].

The study was carried out near the end of the harvest season. Percent cover by C. crispus fronds would be at a minimum; however, it was felt that a more accurate distribution and cover of C. crispus plants could be attained at this time.

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[1]MacFarlane, C., biologist (retired), Nova Scotia Research Foundation Corporation, Dartmouth, N.S.

[2]For ease in comparison of the various seaweed beds mentioned throughout this report, all figures have been compiled as Appendix I.

METHODS AND MATERIALS

A quantitative survey of marine plants of commercial importance (mainly Irish moss) on coastal Prince Edward Island was initiated in 1967 (Judson and Gorazdowska 1968). The technique employed by the latter was adapted for use in the present study. It involved running transects vertical to a base line of 43°E (Fig. 2), on the dates given in Table 1, through each bed at 160 m intervals (100 m intervals through Horses Head bed). The base line kept the distance between transects constant and the angle of each transect common. Unfortunately the line was often an unworkable distance from shore (see Fig. 2); hence, a secondary line closer to the shore was employed. The location for each transect from the latter line was determined by assessing the angle of divergence from the base line (Fig. 2) with the transit and calculating the length of the hypotenuse with the following formula:

$$c = \frac{d}{\mathrm{Cos}(a)}$$

c = calculated distance (hypotenuse)
d = distance between transects (100 m or 160 m)
a = angle of divergence (from base line)

The length of the hypotenuse was measured with a 4 mm dia., 300 m long polypropylene rope marked every 2 m. The transects ran perpendicular to the base line. Two orange and black "shore markers" (1 m^2) were placed on each transect 5 m apart (Fig. 2 and 3). A buoy was anchored by a SCUBA-equipped diver (hereafter referred to as "diver") at both the inner and outer edges of the Irish moss bed in direct line with the two shore markers. The distance from the buoy to the high-tide mark on the shore was calculated by triangulation using the transit to acquire the angles.

Each transect line was demarcated by a 1.3 cm dia. nylon lead-core line, marked at 10 m intervals. It was laid on the ocean bottom from a 12 m boat. The captain of the vessel laid the line along the transect by navigating his boat in such a way as to keep the two shore markers in line. The line was laid from the inner buoy to the outer buoy.

A pair of divers swam the length of each transect; one of them recorded the following observations every 10 m on water-proof paper: time of day, water depth, temperature, ocean bottom substrate type, percent Irish moss, associated plant species, and presence or absence of animal species. The substrate was categorized based on particle size as follows: fines (< 2 cm), cobbles (< 20 cm), rocks (< 120 cm), boulders (>120 cm), and ledge. The observations were made in an estimated 4 m^2 area, centered on the marked nylon lead line. The depth was determined from a marked meter line connected to both a buoy and the diver. The depth in relation to tides was determined, using time of day and tide charts (Anonymous 1978; 1980).

Table 1. The landmark employed as a base line for each commercial bed studied in District 1 and the latitudes and longitudes of the first and last transect.

Commercial bed	Location of base line	Transect no.	Latitude and Longitude	Date studied
South Roseville		1	46°48'11.6"N 64°17'29.6"W	August, 1978
	Beginning of sandstone cliff on western side of Little Miminegash Pond	21	46°49'41.5"N 64°15'54.4"W	
North Roseville	Just to the east of the Little Miminegash Pond Road	0	46°50'10.5"N 64°15'31.4"W	August, 1978
		1	46°50'15.2"N 64°15'29.5"W	
		16	46°51'26.8"N 64°14'41.3"W	
Miminegash Reef		1	46°52'26.9"N 64°14'11.8"W	August, 1980
	To the east of Miminegash wharf at the juncture of shore and wharf	5	46°52'47.2"N 64°14' 2.6"W	
		9	46°53' 3.9"N 64°13'38.5"W	
Cape Gage		1	46°53'51.9"N 64°13'29.3"W	August, 1978
	West side of road at the beach juncture	12	46°54'38.7"N 64°12'26.2"W	
Pleasant View	Same base line as Cape Gage	0	46°54'38.7"N 64°12'26.2"W	August, 1978
		12	46°55'32.6"N 64°11'26.5"W	

...contd.

Table 1. contd.

Commercial bed	Location of base line	Transect no.	Latitude and Longitude	Date studied
Horses Head	West side of road/beach junction	0	46°55'43.9"N 64°11'16.9"W	August, 1978
		1	46°55'45.7"N 64°11'16.5"W	
		6	46°56' 4.2"N 64°11'16.9"W	
Kennys Reef		1	46°56'15.0"N 64°10'56.3"W	July, 1980
	West side of road/beach junction at Waterford	8	46°57' 2.0"N 64°09'47.8"W	
		19	46°57'27.7"N 64°08'42.7"W	

A team of six (all skilled in SCUBA) was employed in groups of two: one pair made observations along the transect while another pair set up adjacent transects; a final pair tended the divers and shore markers from the 5 m fibreglass boat (Fig. 3) or the larger vessel (Fig. 4).

To permit relocation of the surveyed beds a prominent land-based object such as a road, pond, or wharf was identified with each bed (Table 1). As well, the coordinates (latitude and longitude) of two to three transects per bed are given.

The information collected was placed on computer tape for data analysis. Contoured maps of depth and biomass were generated by GPCPII (General Purpose Contouring Program, CALCOMP 1972). An important consideration in producing the contour maps was the size of the grid and neighbourhood points. The selected size affected the quality of the graph both in line accuracy and smoothness. After considerable experimentation, a grid size of 9 x 30 units was found to be adequate for all the contour maps except Miminegash Reef. Due to its unusual shallowness and narrow center channel, a grid size of 20 x 20 units was chosen which presented the data more realistically. A xynetics plotter was used to produce high-quality maps.

RESULTS

The approximate location of the seven major commercial Irish moss beds and their north/west coordinates are given in Figure 1 and Table 1 respectively. The length of each transect, mean percent cover by Irish moss, mean depth, and the area between transects are available in Appendix II (Tables A to G). The combined area of all seven beds was 5,124,600 m^2 (512.3 ha); the overall mean percent cover by Irish moss was 17.9%. All major substrate types were observed on all beds, with the following exceptions: rock was not observed on the Cape Gage bed, nor was boulder observed on either Pleasant View or Cape Gage beds (Table 2). Ledge was by far the most common substrate (31.3% - Fig. 5); cobble (9.7%) and fines (8.9%) were the second and third most abundant types (Table 2). All major substrate types supported Irish moss (Fig. 6); ledge, rock, and cobble had the highest coverage (23.0%, 21.7%, and 16.4% respectively) - significantly ($P \leq 0.05$) higher than boulder (13.7%) and fines (3.2%). The substrate combinations that supported the highest percent cover was ledge and cobbles (26.8%) and ledge and rock (23.5%) (Fig. 6). The mean depth below chart datum of each bed (Table 5) ranged between 2.9 m (Cape Gage and South Roseville) and 4.1 m (Kennys Reef), the differences being significant ($P \leq 0.05$). Irish moss occurred in commercial quantities between 0.5 m and 7.5 m water depth; the differences in percent cover with depth were not significant ($P \leq 0.05$) (Fig. 7).

The following is a brief description of each bed noting bottom, depth contours, substrate type, and distribution of Irish moss.

Table 2. The percentage substrate type per commercial Irish moss bed in District 1.

Substrate Type	Percentage substrate type							
	Kennys Reef	Horses Head	Pleasant View	Cape Gage	Miminegash Reef	North Roseville	South Roseville	All areas
Fine	18.8	8.4	5.8	2.4	12.7	4.3	9.4	8.9
Cobbles	0.9	7.4	8.5	17.3	2.6	17.8	13.0	9.7
Cobbles and fine	2.0	6.8	1.1	4.2	9.6	2.8	8.6	4.4
Rock	5.5	2.1	3.5		4.4	2.8	1.3	2.9
Rock and fine	5.0		0.7	0.7	6.2	1.5	0.6	2.2
Rock and cobbles	4.3	6.3	10.3	11.6	3.4	10.4	10.3	8.4
Rock, cobbles, and fine	3.2	2.1	0.6	0.3	5.2	0.4	1.0	1.7
Boulders	9.4	0.5			4.3	3.3	0.8	2.6
Ledge	26.7	44.2	39.4	29.2	23.6	32.4	28.2	31.3
Ledge and fine	8.9	6.8	7.8	8.5	9.6	2.8	15.1	8.7
Ledge and cobbles	4.4	9.5	13.6	15.2	3.9	12.8	5.9	9.6
Ledge, cobbles, and fine	1.8	0.5	0.8	2.2	6.5	1.3	2.5	2.2
Ledge and fine	5.2	2.6	6.7	3.6	2.9	5.4	2.9	4.5
Ledge, rock, and fine	3.4	1.1	0.1	2.9	3.4	0.2	0.2	1.6
Ledge, rock, and cobbles	0.6	1.6	1.0	1.7	1.8	1.7	0.2	1.1

SOUTH ROSEVILLE

Of the seven beds studied this bed was both the longest and narrowest and ranked fourth in area (78.2 ha). The most prevalent substrate types on it in order of abundance were ledge (28.2%), ledge-fines (15.1%), and cobble (13.0%) (Fig. 9 and 11). The overall mean percent cover by Irish moss was 17.5% (Table 3); cover peaked at 2 m to 3 m water depth, but there was little difference in cover between depths of 0.5 m to 6.5 m (Fig. 10).

The bottom shelved to the east at the western end of the bed, but from about the midpoint eastward the shelving dropped to the north (Fig. 12). Irish moss cover increased from east to west and was most prevalent in the flat-bottomed area between Transects 2 and 8 (Fig. 13).

NORTH ROSEVILLE

Of all the beds studied (Table 3) this bed ranked fifth in area (68.0 ha). The most abundant substrate types were ledge (32.4%) and cobble (17.8%); few fines were observed (Fig. 14 and 16). The overall mean cover by Irish moss was 15.1% (Table 3), which peaked with increasing depth to 2.5 m then decreased with depth to 5.0 m (Fig. 15). Although Irish moss cover was sparse at 6.0 m, cover at 5.0 m was as high as at 2.0 m.

The pattern of depth contours varied from west to east. The central portion of the bed, between Transects 4 and 11, was relatively flat, dropping gradually from 1.0 m to 4.0 m (Fig. 17); percent Irish moss cover was high (Fig. 18). The eastern end dropped quickly, shelving both to the east and west. Here, Irish moss cover was sparse. The western slope had slightly better coverage.

MIMINEGASH REEF

Of the beds studied, Miminegash Reef ranked sixth in area at 56 ha (Table 3) and had the lowest incidence of ledge (23.6%), a low concentration of cobbles, and the second highest concentration of fines (Fig. 19 and 21; Table 2). Percent cover by Irish moss (9.7%, Table 3), lowest of all beds studied (Fig. 8), peaked at 1.5 m water depth and then decreased gradually to 7.0 m (Fig. 20).

The bottom relief was rugged, consisting of a series of peaks and gulleys (Fig. 22). The percent cover by Irish moss was sparse throughout (Fig. 23); Transect 8 had the highest mean cover (19.7%).

Table 3. The mean dimensions and area of each major commercial Irish moss bed in District 1.

Commercial bed	Percentage cover of Irish-moss*	Mean dimensions and area			
		Average width (m)	Range in width (m)	Length (m)	Area (m^2)**
South Roseville	17.5	238.6	50-460	3,200	782,400
North Roseville	15.1	277.5	170-450	2,400	680,000
Miminegash Reef	9.7	418.9	180-730	1,280	562,400
Cape Gage	20.0	486.9	350-610	1,920	928,800
Pleasant View	27.3	588.3	400-700	1,760	1,044,000
Horses Head	21.8	306.7	160-380	500	163,000
Kennys Reef	12.6	334.7	150-690	2,880	964,000

*Mean cover by Irish moss is 17.9%.
**Grand area for all beds combined = 5,124,600 m^2.

CAPE GAGE

This bed ranked third in area (93 ha), slightly smaller than Kennys Reef (Table 3). Rock or boulders were not observed on the bed and fines were low (Fig. 24); ledge and cobbles were the most abundant bottom types (Fig. 26). Overall, percent Irish moss cover (20.0%) ranked third, behind the Horses Head bed. Irish moss peaked in percent cover at 1.0 m water depth then decreased in abundance to 5.5 m (Fig. 25).

The bulk of the bed was at prime depth for Irish moss (2 m to 3 m). For the most part the bottom shelved gently to the east (Fig. 27); steeper gradients were observed on the eastern and western ends. With the exception of pockets of high Irish moss cover (up to 60%) in these latter areas, plant cover was relatively uniform throughout the bed (Fig. 28).

PLEASANT VIEW

Of the beds studied this was the largest in area (104 ha), due mainly to its uniformly broad width (Table 3). The incidence of rock was low and boulders were not observed (Fig. 29 and 31); concentrations of fines ranked fifth, of the beds studied, and percent ledge ranked second (Table 2). Irish moss coverage was 27.3% (Table 3), the highest of all beds studied (Fig. 8). Plant cover peaked at 2.5 m water depth and then decreased gradually to 7.5 m (Fig. 30).

The water depths, slope, and orientation of shelving was similar to the Cape Gage bed (Fig. 32); the outer edge, however, was in deeper water (Fig. 33). Irish moss cover was high throughout most of the bed, with the central portion having the highest concentrations (up to 100% - Fig. 28). The eastern edge of the bed had the only sparse distribution of plants. The lowest mean concentration of Irish moss per transect was noted on Transect 10 (16.8% - Appendix II - Table F). This may have been due to the freshwater entering just south of the bed (Fig. 33).

HORSES HEAD

Of those studied, this was the smallest bed in area (16.3 ha) (Table 3). Ledge was considerably more abundant than other bottom types (Fig. 34 and 36), and its concentration (44.2% - Table 2) was higher than that observed for other beds. The incidence of rock and cobble was extremely low and percent fines and cobble were each less than 10%. Percent Irish moss cover was 21.8%, second in abundance next to the Pleasant View bed (Table 3; Fig. 8). Irish moss cover increased with water depth to 4.5 m and then decreased in abundance to 8 m (Fig. 35).

The bottom topography resembled that of Miminegash Reef (Fig. 22 and 37) with a series of peaks and gullies. Irish moss was distributed throughout most of the bed, but four pockets of concentrations were obvious (Fig. 38). A trough of low concentration ran along Transect 4.

KENNYS REEF

Next to South Roseville, this bed ranked second in both length and area (96.4 ha - Table 3). The bottom had a low incidence of cobble and ledge (Fig. 39 and 41) compared to most other beds studied (Table 2) but the highest concentration of fines (18.8%), rock (5.5%), and boulders (9.4%). Cover by Irish moss ranked sixth (12.6%), only slightly higher than Miminegash Reef (Table 2; Fig. 8). Plant cover increased with water depth to 3.5 m and then decreased to 7.0 m depth; cover at 7.5 m was higher than at 2.0 m to 2.5 m depth (Fig. 40).

Kennys Reef is both narrow and deep (Fig. 42). The western side did not rise above 3.0 m water depth, and the majority of the eastern end was in 5.0 m of water. The middle of the bed dropped quickly to the north to 9.0 m of water (Transect 11), but between Transects 11 and 14 there appeared to be a flat stretch of bottom. Irish moss cover was sparse for the first five transects (Fig. 43) but increased markedly between Transects 7 and 11. Cover was then patchy to the eastern end of the bed.

DISCUSSION

The bottom of a typical Irish moss bed in Marine Plant Harvesting District 1 (Fig. 1) is made up of five major substrate types and their combinations (Fig. 5; Table 2): boulder (2.6%), rock (2.9%), fines (8.9%), cobble (9.7%), and ledge (31.3%). As would be expected, the percent Chondrus cover on fines (3.2) is significantly ($P \leq 0.05$) less than on all other major substrate types (Table 4). Fines have a deleterious effect on the macrophyte carrying capacity of the other substrate as well. For example, only 9% ledge was not covered by Chondrus, whereas when fines were combined with ledge 19% was bare (Table 5). When C. crispus is attached to ledge in combination with fines it is likely often covered by shifting fines, being a low-tufted plant.

Ledge had a significantly ($P \leq 0.05$) higher percent cover than all other major substrate types but rock (21.7%); thus, there is a significant ($P \leq 0.05$) direct correlation ($r = 0.80$) between percentange occurrence of Chondrus in a bed and the abundance of ledge (Fig. 44).

Cobbles are an important substrate as they are abundant, and only 4.7% of the cobbled area was devoid of Chondrus (Table 5). Sharp and Roddick (1980) noted that Irish moss dragrakes off southwestern Nova Scotia disrupted cobbles; this no doubt occurs here as well.

Table 4. Percent Irish moss cover per substrate type for all commercial beds combined in District 1. Ranked according to Tukey ($P \leq 0.05$). Grand n = 3,508 [percent transformed by Arc sin (Sokal and Rohlf 1969)].

Substrate type	Mean % cover	Arc sin transformation std. error	Statistical Rank ($P \leq 0.05$)
Fine (n = 313)	3.2	0.0321±0.0048	
Fine, rock, ledge (n = 57)	9.9	0.1002±0.0167	
Fine, rock (n = 76)	10.7	0.1093±0.0165	
Fine, ledge (n = 305)	11.9	0.1230±0.0098	
Fine, cobble (n = 153)	12.7	0.1314±0.0144	
Fine, cobble, rock (n = 58)	13.0	0.1316±0.0173	
Boulder (n = 96)	13.7	0.1419±0.0199	
Cobble, ledge, fine (n = 76)	15.7	0.1630±0.0225	
Cobble (n = 341)	16.4	0.1694±0.0096	
Cobble, rock (n = 296)	16.8	0.1752±0.0122	
Cobble, rock, ledge (n = 40)	17.0	0.1761±0.0300	
Rock (n = 102)	21.7	0.2296±0.0241	
Rock, ledge (n = 159)	23.0	0.2493±0.0206	
Ledge (n = 1,098)	23.5	0.2498±0.0089	
Ledge, cobble (n = 338)	26.8	0.2841±0.0138	

Table 5. The percentage of each substrate type per commercial bed not supporting Irish moss.

Substrate type	Percentage of quadrats without Irish moss							
	Kennys Reef	Horses Head	Pleasant View	Cape Gage	Miminegash Reef	North Roseville	South Roseville	All areas*
Fine	75.6	37.5	57.1	78.6	32.7	100.0	87.8	68.1
Cobble	0.0	0.0	6.6	4.0	20.0	6.1	1.5	4.7
Cobble and fine	15.4	7.7	0.0	8.3	8.1	7.7	0.0	5.9
Rock	16.7	0.0	4.0	-	0.0	7.7	0.0	7.8
Rock and fine	39.4	-	60.0	0.0	12.5	14.3	0.0	26.3
Rock and cobble	7.1	16.7	2.7	11.9	0.0	4.2	3.7	6.1
Rock, cobble, and fine	14.3	0.0	0.0	0.0	0.0	50.0	0.0	6.9
Boulder	41.0	0.0	-	-	12.5	0.0	0.0	28.4
Ledge	21.1	1.2	6.0	4.1	16.5	8.7	8.2	9.3
Ledge and fine	36.2	0.0	14.3	14.3	10.8	46.2	15.2	19.0
Ledge and cobble	10.3	0.0	1.0	2.3	0.0	1.7	3.2	2.4
Ledge, cobble, and fine	16.7	0.0	0.0	0.0	0.0	0.0	7.7	4.0
Ledge and rock	17.6	0.0	0.0	0.0	9.1	12.0	0.0	6.3
Ledge, rock, and fine	40.9	0.0	100.0	5.9	0.0	0.0	0.0	19.3
Ledge, rock, and cobble	25.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5

*14.5% of the total area without Irish moss.

Rock had a high percent cover of Irish moss but was not all that common in the beds as both rock and boulder impede dragrakes; a high percentage of either would preclude the area for dragraking.

Irish moss peaked in biomass on rocky shores of the Gulf of Maine at between 0.5 m above chart datum to 4.0 m below chart datum (Prince and Kingsbury 1973; Pringle and Semple 1980). Chondrus, however, has been observed at 24 m below low water off the Isle of Shoals, Maine, an exposed coastal site (Mathieson 1979). Irish moss in the southern Gulf of St. Lawrence occurs from just below low water down to at least 10 m (MacFarlane 1966), although Aldrich et al. (1971) noted it was uncommon in Port-au-Port Bay, Newfoundland, below 7 m.

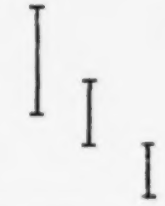
There was a significant difference ($P \leq 0.05$) in depth of the beds studied in District 1 (Table 6), but there was not a direct correlation ($r = 0.46$) between mean depth of bed and percent Chondrus cover. As well, within the depths of the beds there was not a significant difference between Chondrus cover and depths between 0.5 m below chart datum and 7.0 m below chart datum. Below 7.0 m, although C. crispus was present, it likely did not occur in densities sufficiently high to yield the required catchability.

These commercially important beds were not a monoculture; at least 17 other plant taxa were associated with Irish moss (Table 5). Chondrus was by far the most frequently occurring species; it was observed in 85.5% of the quadrats. Saccorhiza dermatodea was the rarest species (0.1% occurrence), whereas certain "fine reds" (Cystoclinuim purpureum, Polyisiphonia spp., and Ceramium spp.) were present in 54.3% of the area (Table 6). This compares favourably to the annual by-catch of other plant taxa observed in the Irish moss harvest, which ranges between 10% and 20% of the dry weight (Pringle unpub. data).

The abundance of Chondrus, compared to the other plant taxa (Table 7), suggests that Chondrus can outcompete these other taxa in beds that have been commercially dragraked for about thirty years. The morphology of Chondrus is likely the main characteristic that permits it to withstand dragraking. A plant consists of a thin, perennating, discoid holdfast and numerous upright fronds (see Taylor and Chen 1973) in various stages of maturity. The fronds are removed by binding between the tines of the passing dragrake. Portions of holdfast often come free from the substrate during raking, but rarely is a complete holdfast removed (Pringle 1979). Hence, the technique leaves the bulk of the holdfasts and the growth immature fronds attached to the substrate. Most other species are either removed completely by the dragrake, or the remaining holdfast does not give rise to upright fronds.

The possible selective removal of non-Chondrus taxa by dragrakes may explain the harvesters' contention that dragraking expands bed size. During years of high demand for Irish moss it may be worthwhile for the harvester to crop the margins of the

Table 6. The mean depth of each Irish moss bed in District 1.

Irish moss bed	Bed mean depth ±SD (mm below chart datum)		Statistical signficance*
Cape Gage	2.9	±1.0	
South Roseville	2.9	±1.2	
North Roseville	3.0	±0.9	
Horses Head	3.2	±1.2	
Pleasant View	3.4	±1.2	
Miminegash Reef	3.9	±1.3	
Kennys Reef	4.1	±1.5	

*Those not united by a common vertical bar are significantly different ($P \leq 0.05$).

Table 7. Frequency of observation of Irish moss and other taxa in Irish moss beds in District 1 during 1978.

Taxa observed	No. of observations	Frequency (%)
Chondrus crispus Stackh. (Irish moss)	3,000	85.5
Fine reds (Cystocolonium sp., Polysiphonia spp., Ceramium sp.)	1,906	54.3
Halopteris Kutzing sp. (monkey fur)	1,741	49.6
Corallina officinalis Linnaeus	1,331	37.9
Chorda Stackh. spp. (boot lace)	714	20.4
Phyllophora Greville spp. (false moss)	662	18.9
Laminaria Lamouroux spp. (kelp)	567	16.2
Polyides rotundus Grev.	502	14.3
Palmaria palmata O. Kuntze (dulse)	266	7.6
Ahnfeltia plicata Fries (wire weed)	175	5.0
Fucus Linnaeus spp. (rock weed)	153	4.4
Chordaria flagelliformis C. Ag.	143	4.1
Furcellaria lumbricalis Lamour (horse tail)	76	2.2
Desmarestia Lamouroux spp.	29	0.8
Chaetamorpha Kutzing spp. (green string)	8	0.2
Saccarhiza dermatodea J. Ag.	4	0.1
Total	3,508	

beds where the percentage dry weight of Chondrus in the standing crop might be only 40% to 50%. However, with the selective removal of competing perennials the first year, the percentage dry weight of Chondrus in the crop the following year from these areas will increase, making dragraking even more worthwhile.

There were patches of ledge substrate (Table 6) within each bed [ranged between 1.2% (Horses Head) and 21.1% (Kennys Reef)] that did not support Irish moss. One area in the Cape Gage bed has been barren for at least seven years (Fig. 45). The reasons for this are not known. Given the considerable spore production (Pringe unpub. data), one would assume colonization of any barren area after a couple of years. There is grazing by Littorina spp. and the green sea urchin (Strongylocentrotus droebachiensis Müller) within the beds, but it does not appear to be sufficient to maintain these barrens. Other possibilities are scouring by ice, dragrakes, and rocks. The barren area under observation for seven years (Fig. 45) is lined with rocks; water surge or ice movement may frequently move these rocks across this area, thereby removing any young plants. Experimental seeding of the area could test this hypothesis.

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APPENDIX I:

Report Figures

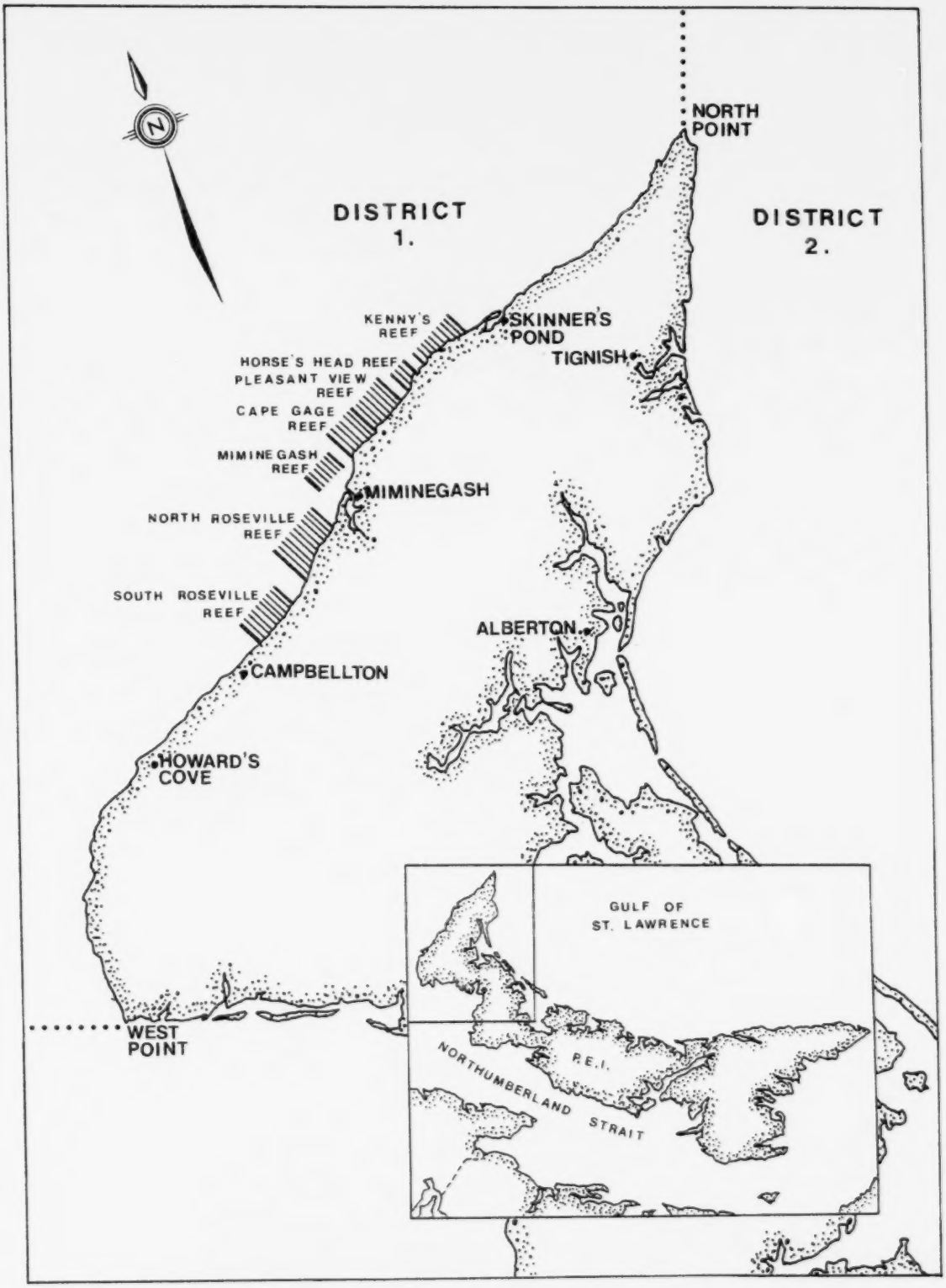

Figure 1. The major commercial Irish moss beds off western Prince Edward Island (the vertical lines denote location of bed).

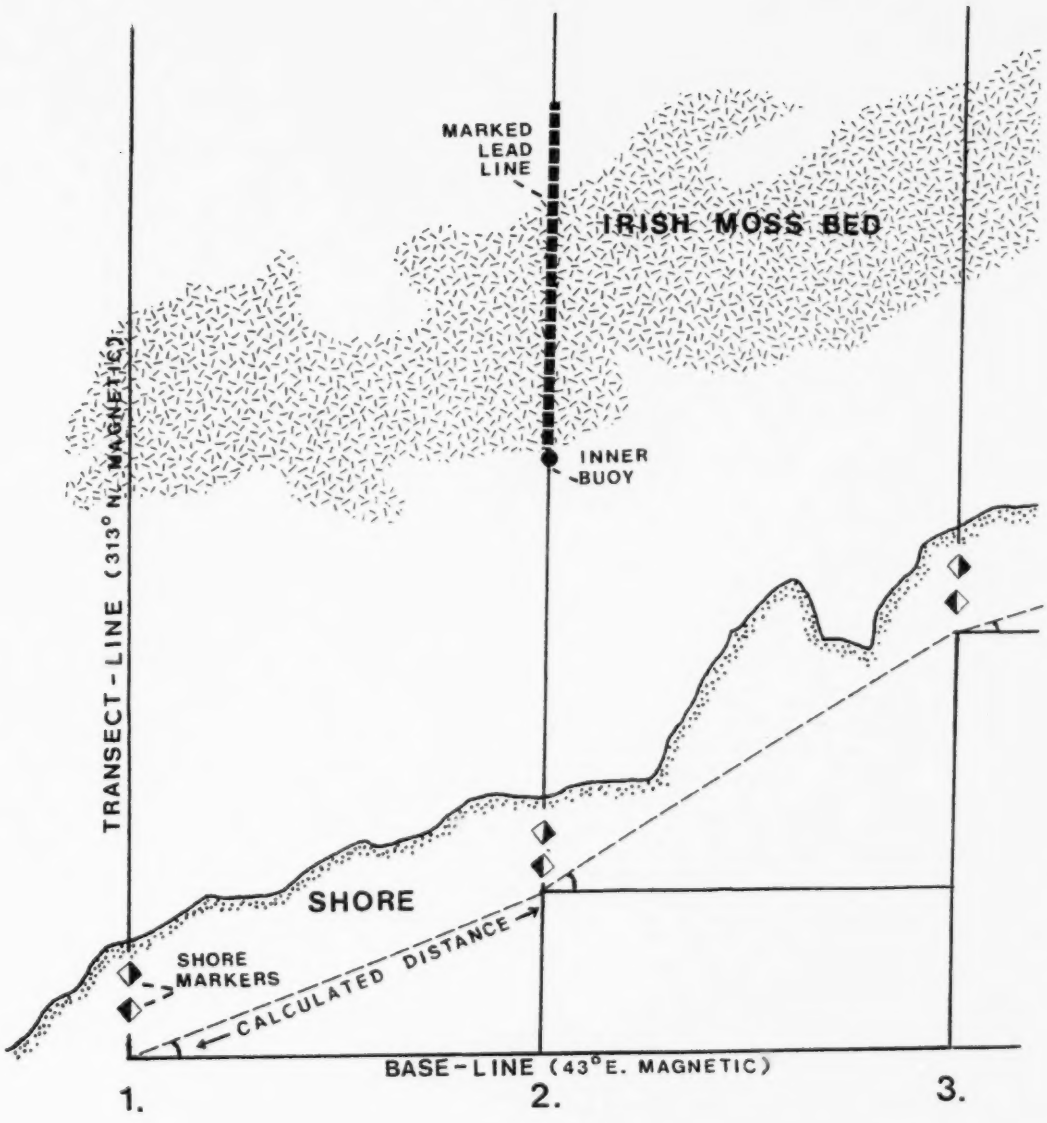

Figure 2. Schematic diagram of the transect sampling technique employed to assess substrate and macrophyte distribution in the major commercial Irish moss beds in District 1.

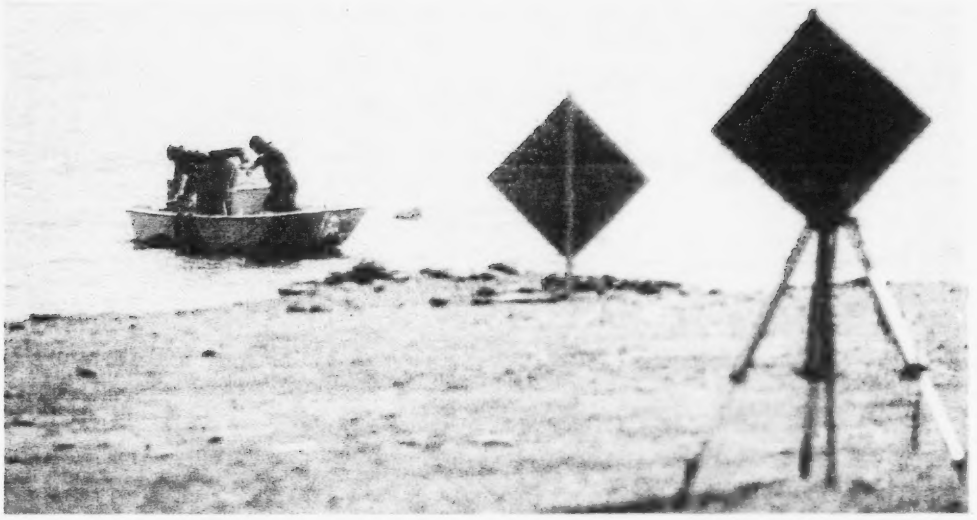

Figure 3. Diver on a transect at the inner edge of an Irish moss bed. The buoy, which is in line with the shore marker (photo right), is connected to the nylon, lead line which demarcates transect.

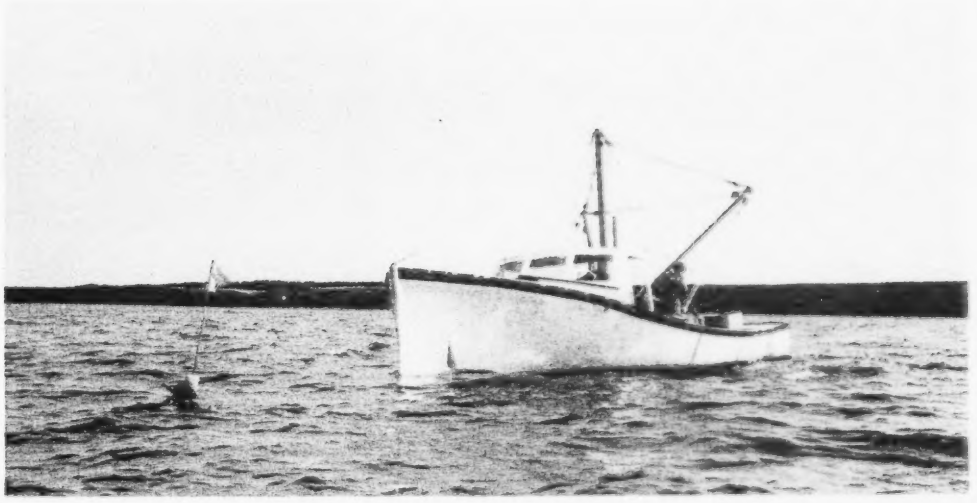

Figure 4. 12 m boat recovering a diver at the outer edge (demarcated by the high flyer) of an Irish moss bed.

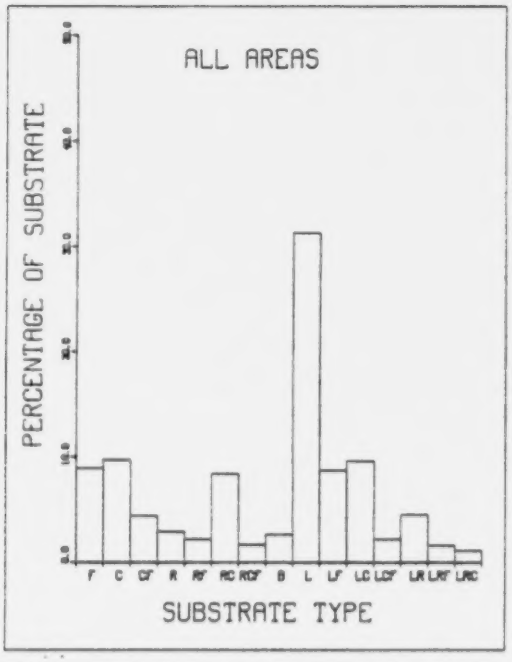

Figure 5. Grand mean (all seven commercial beds combined) percentage occurrence of each substrate type (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

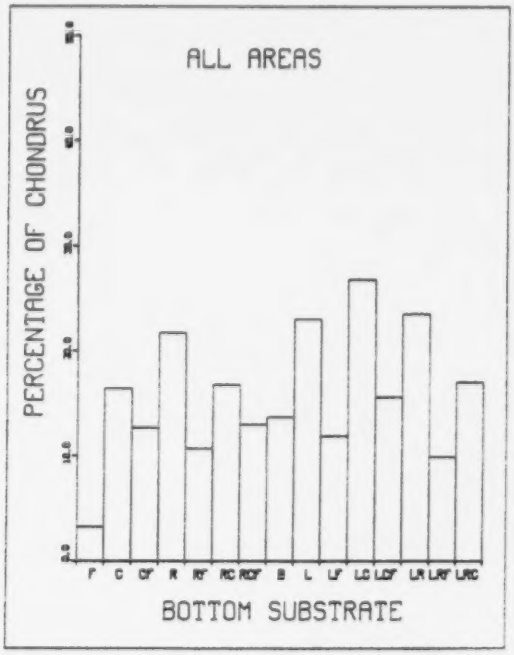

Figure 6. Grand mean (all seven commercial beds combined) percent cover by Irish moss per substrate type.

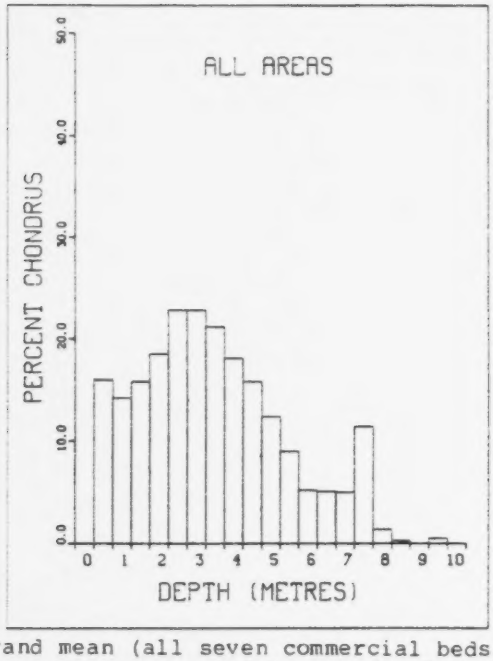

Figure 7. Grand mean (all seven commercial beds combined) percent cover by Irish moss for 0.5 m depth intervals below chart datum.

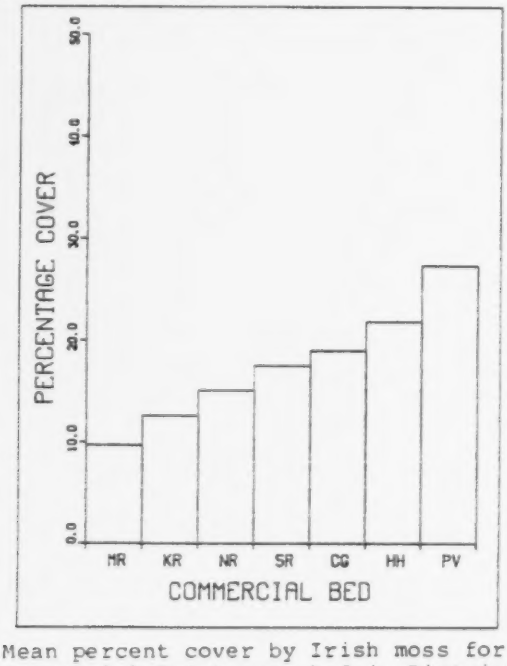

Figure 8. Mean percent cover by Irish moss for each major commercial Irish moss bed in District 1 (MR = Miminegash Reef, KR = Kennys Reef, NR = North Roseville, SR = South Roseville, CG = Cape Gage, HH = Horses Head, and PV = Pleasant View).

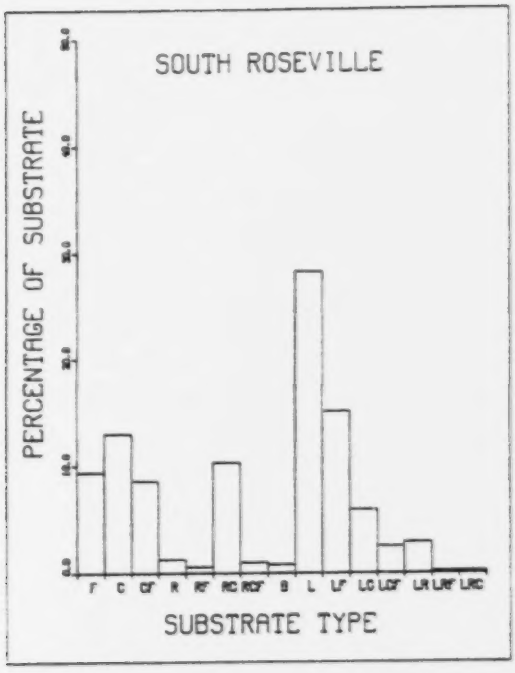

Figure 9. Percentage occurrence of each substrate type on the South Roseville Irish moss bed (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

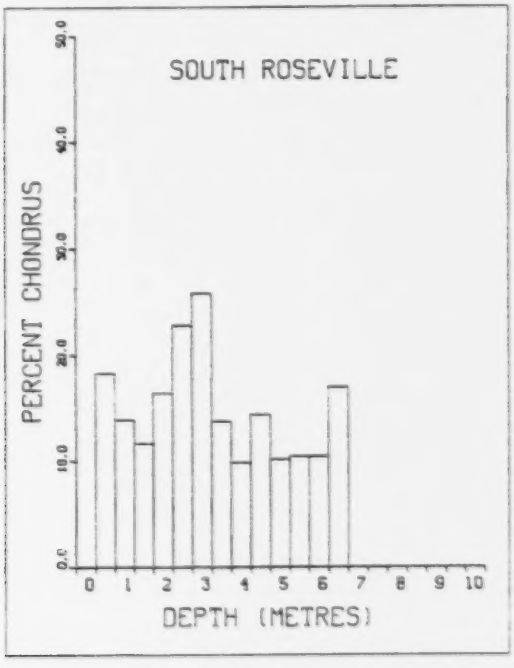

Figure 10. Percentage cover by C. crispus at 0.5 m depth intervals below chart datum on the South Roseville bed.

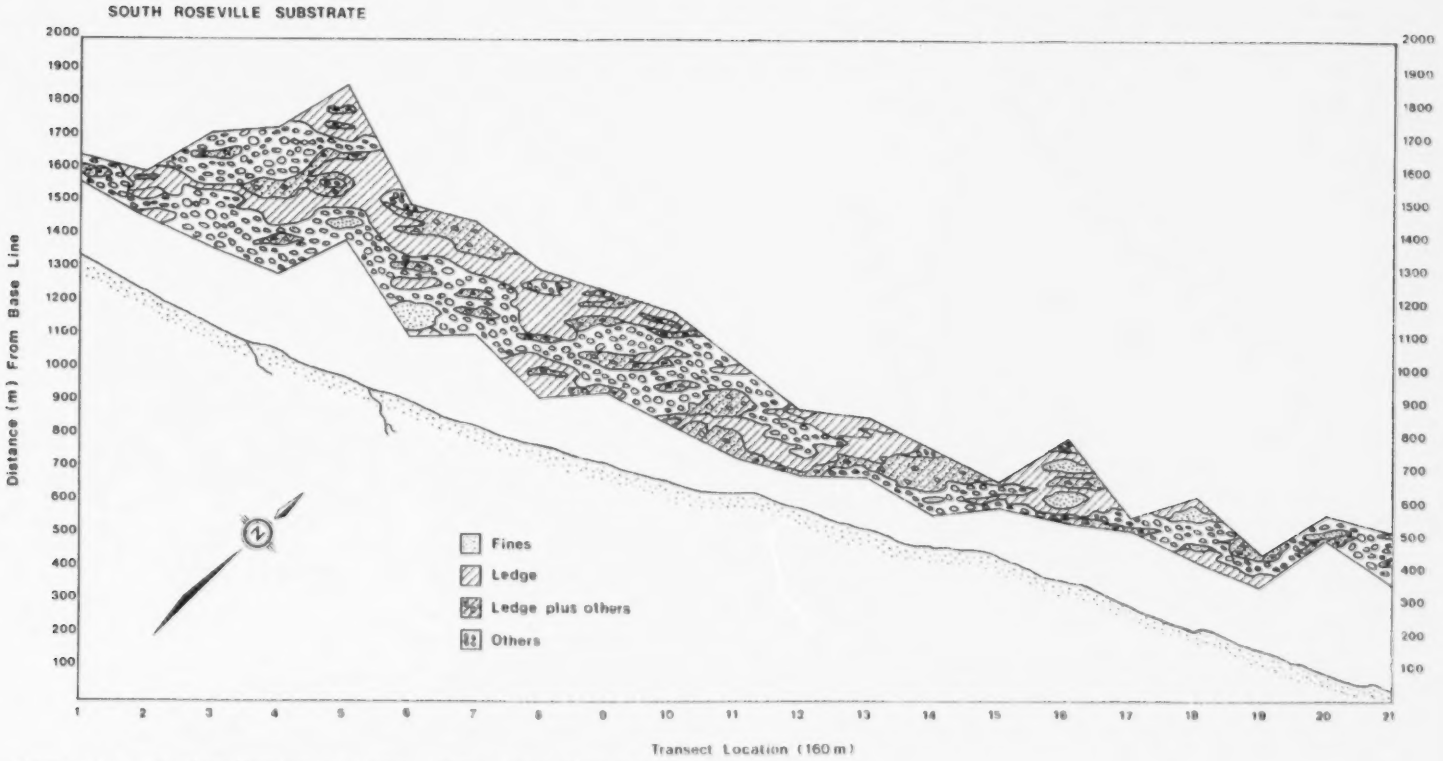

Figure 11. The distribution of fines, ledge, ledge plus others, and "others" (boulders, rock, and all other substrate types excluding the previously mentioned) on the South Roseville Irish moss bed.

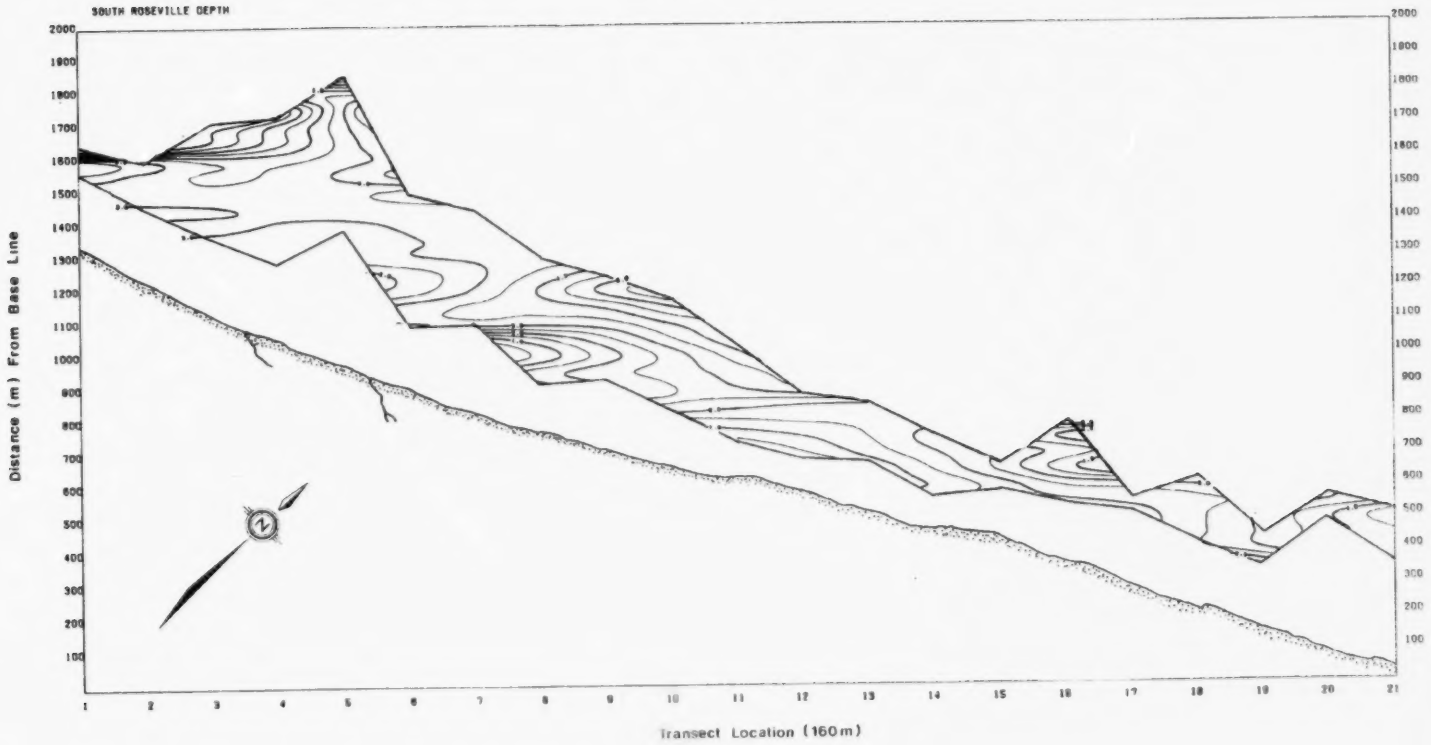

Figure 12. Depth contours (m) below chart datum on the the South Roseville Irish moss bed.

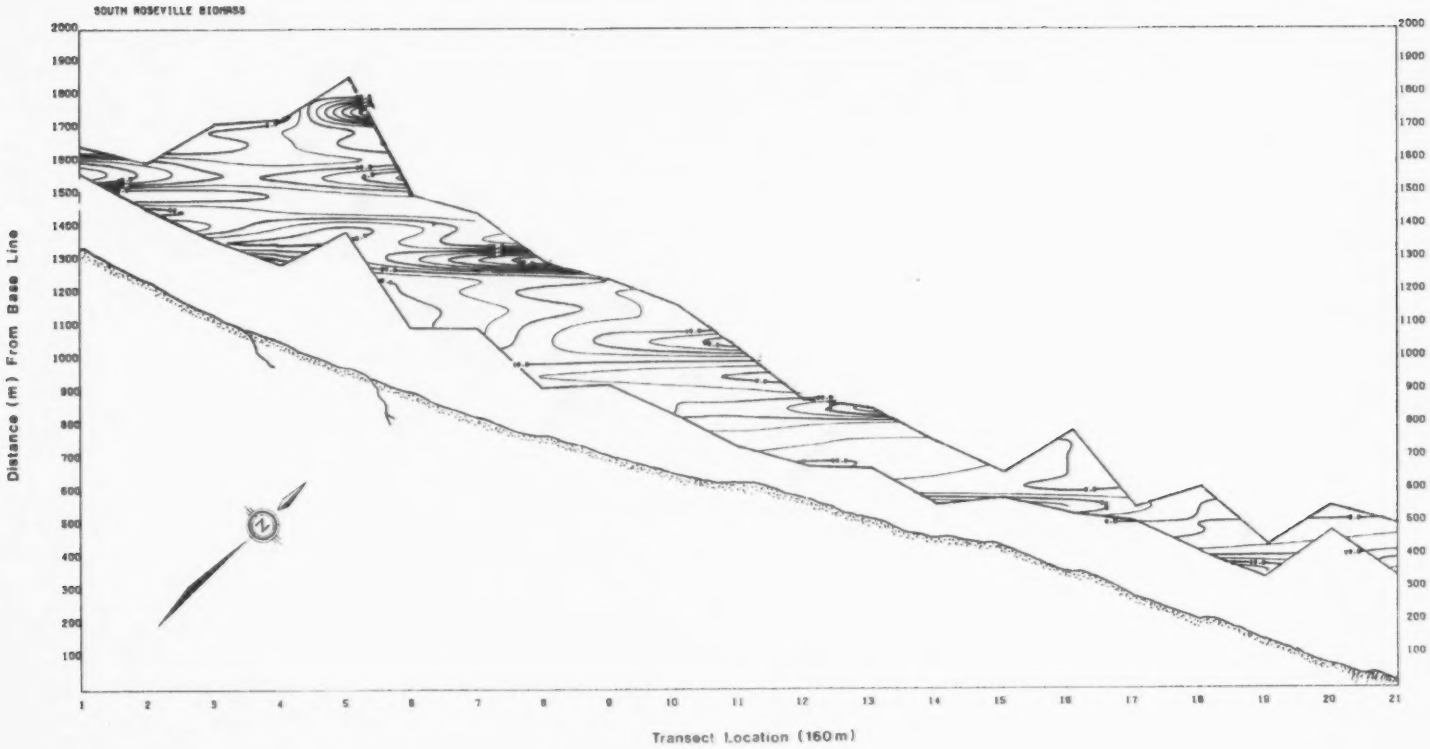

Figure 13. Biomass contours (% cover by C. crispus) on the South Roseville bed.

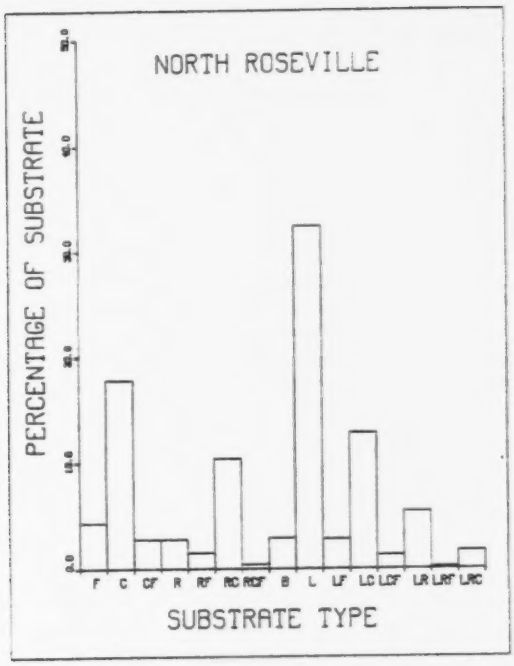

Figure 14. Percentage occurrence of each substrate type on the North Roseville Irish moss bed (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

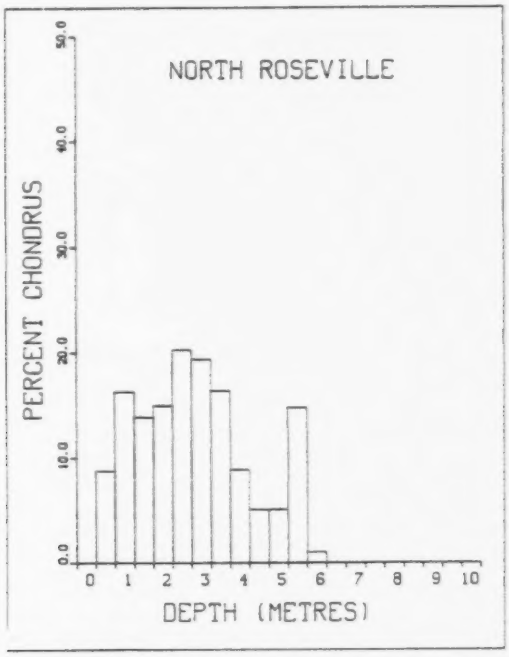

Figure 15. Percentage cover by C. crispus at 0.5 m depth intervals below chart datum on the North Roseville Irish moss bed.

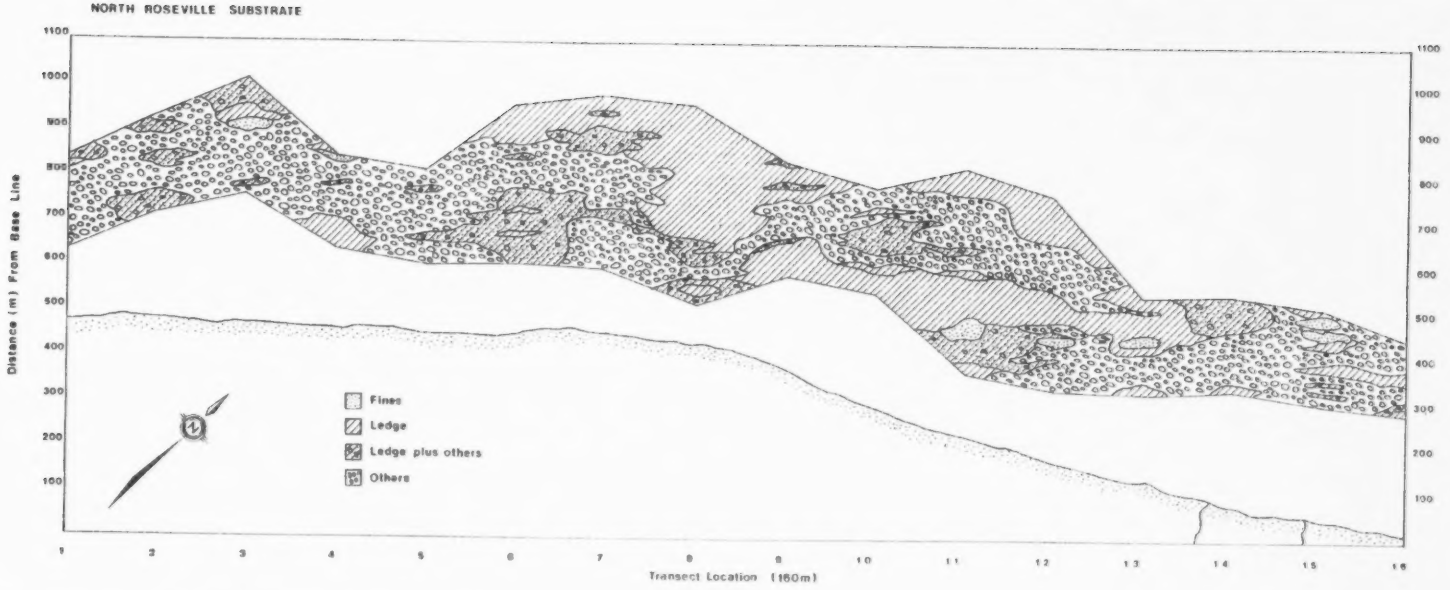

Figure 16. The distribution of fines, ledge, ledge plus others, and "others" on the North Roseville Irish moss bed.

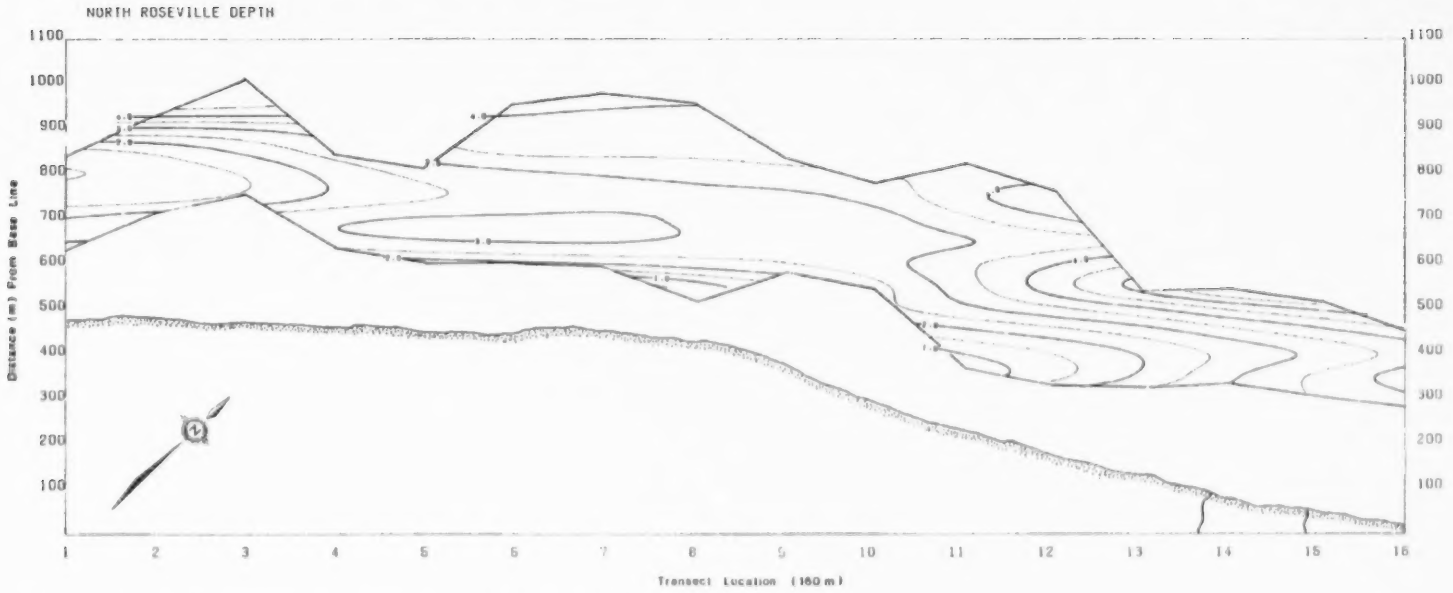

Figure 17. Depth contours (m) below chart datum on the North Roseville Irish moss bed.

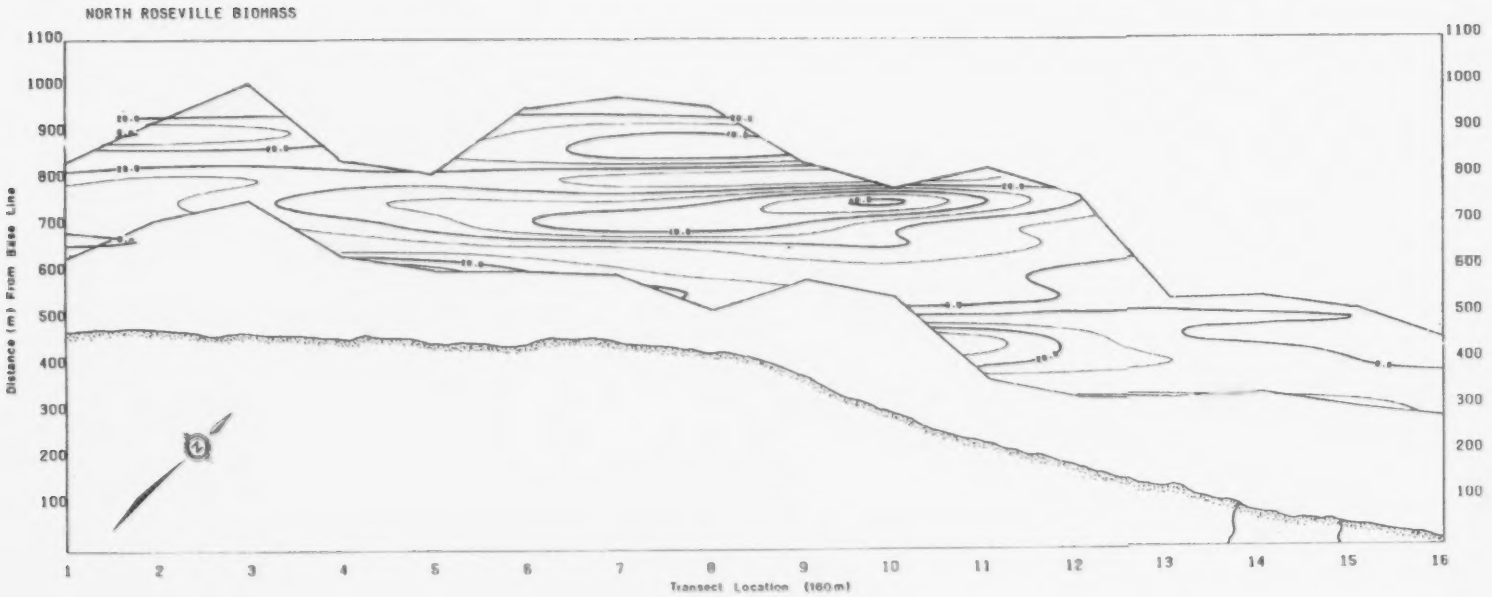

Figure 18. Biomass contours (% cover by C. crispus) on the North Roseville Irish moss bed.

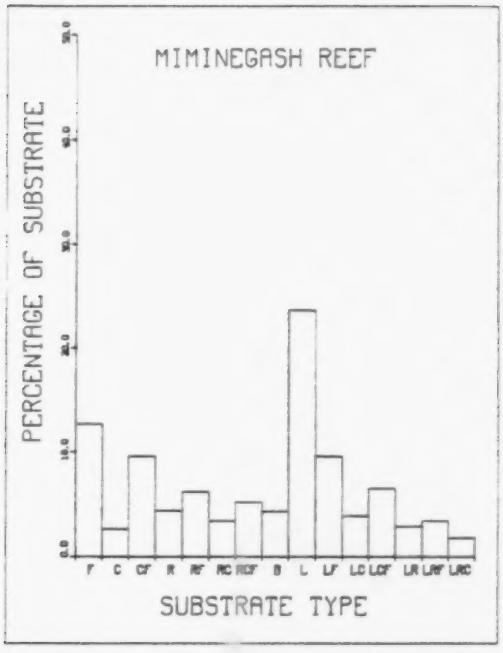

Figure 19. Percentage occurrence of each substrate type on the Miminegash Reef Irish moss bed (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

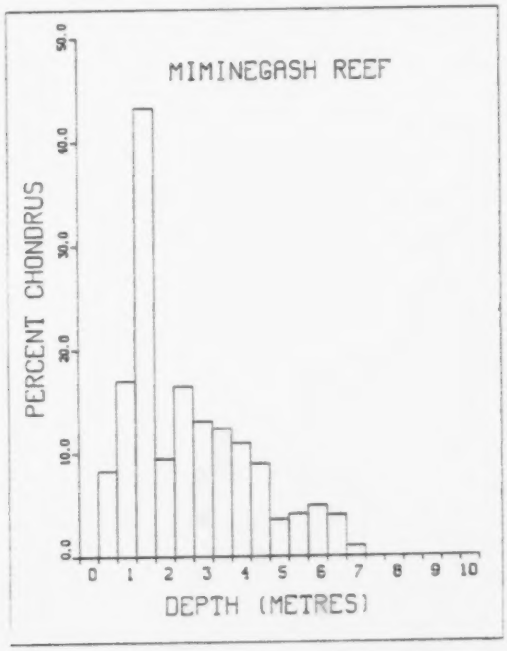

Figure 20. Percentage cover by C. crispus at 0.5 m depth intervals below chart datum on the Miminegash Reef Irish moss bed.

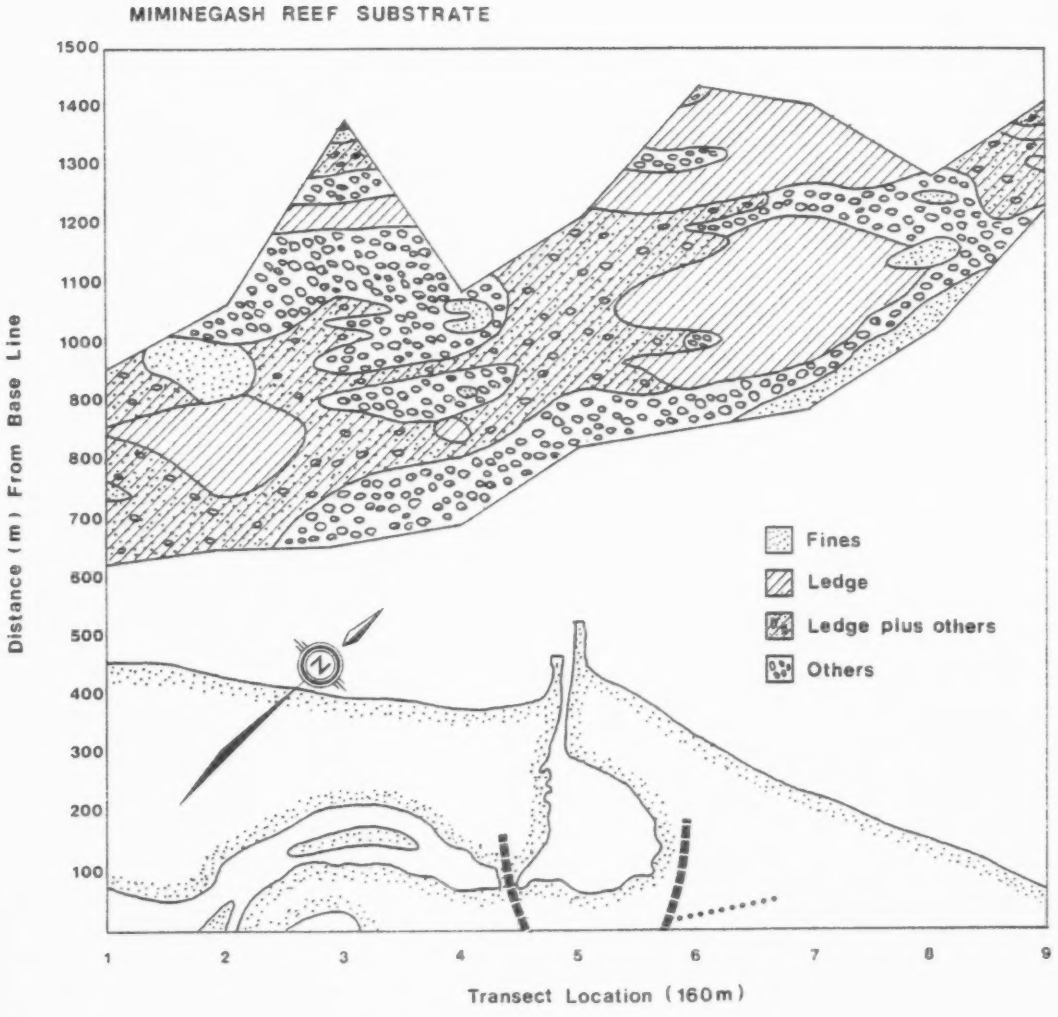

Figure 21. The distribution of fines, ledge, ledge plus others, and "others" on the Miminegash Reef Irish moss bed.

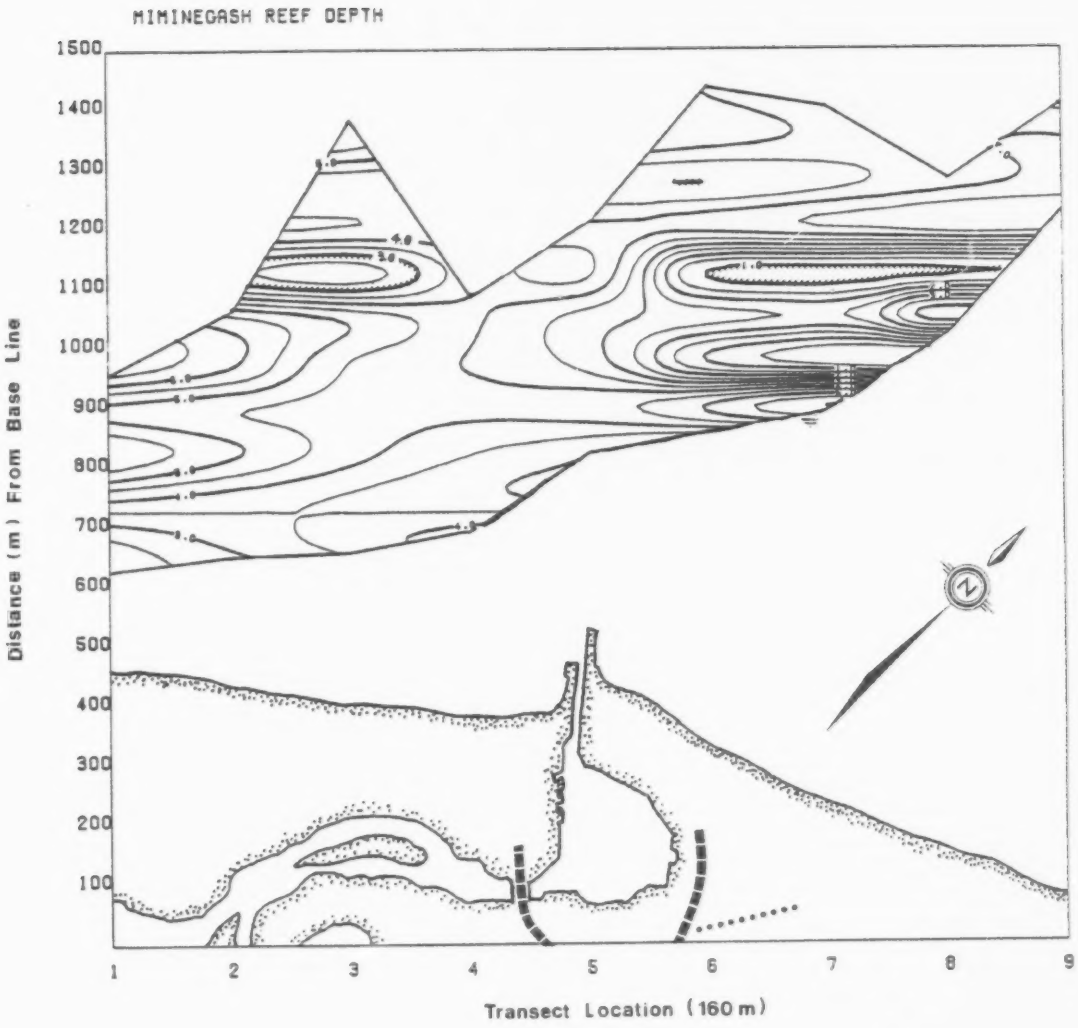

Figure 22. Depth contours (m) on the Miminegash Reef Irish moss bed.

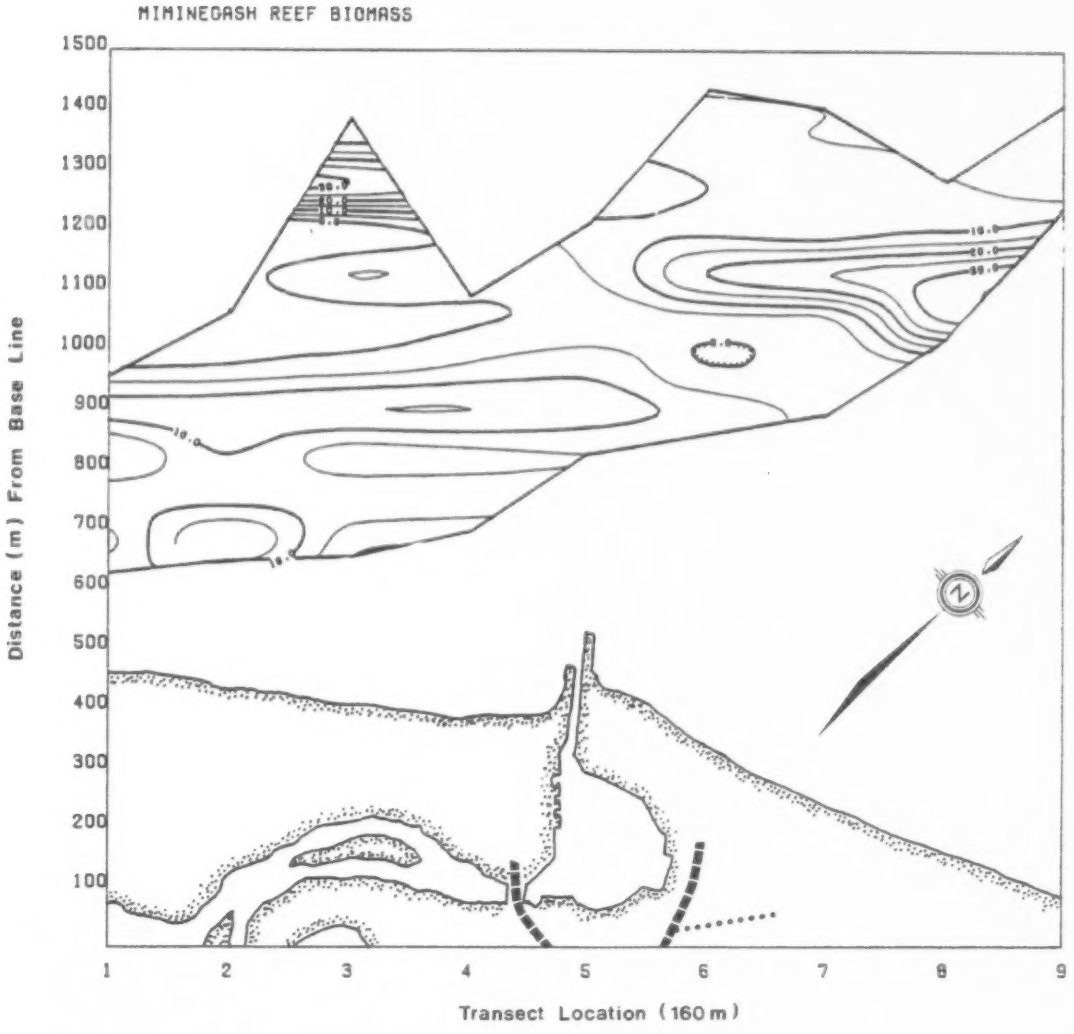

Figure 23. Biomass contours (% cover by C. crispus) on the Miminegash Reef Irish moss bed.

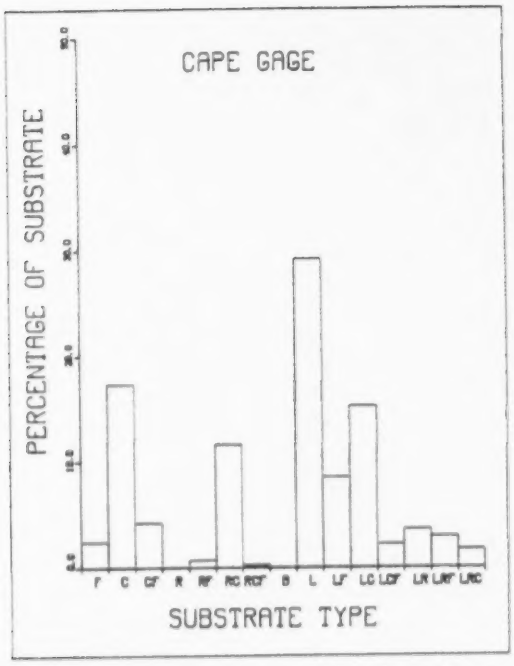

Figure 24. Percentage occurrence of each substrate type on the Cape Gage Irish moss bed (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

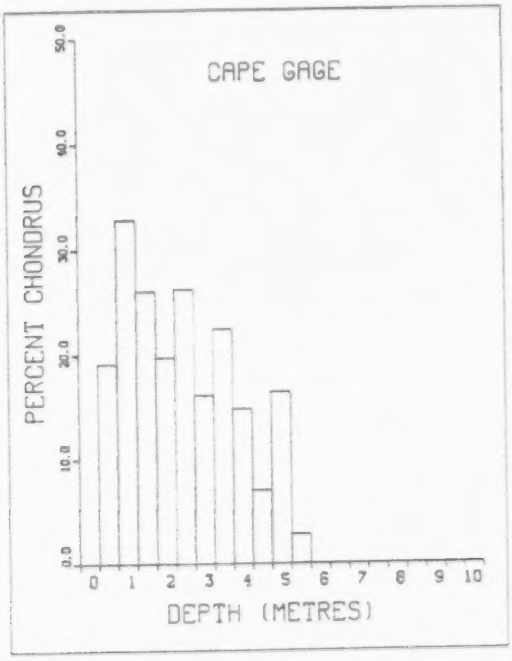

Figure 25. Percentage cover by C. crispus at 0.5 m depth intervals below chart datum on the Cape Gage Irish moss bed.

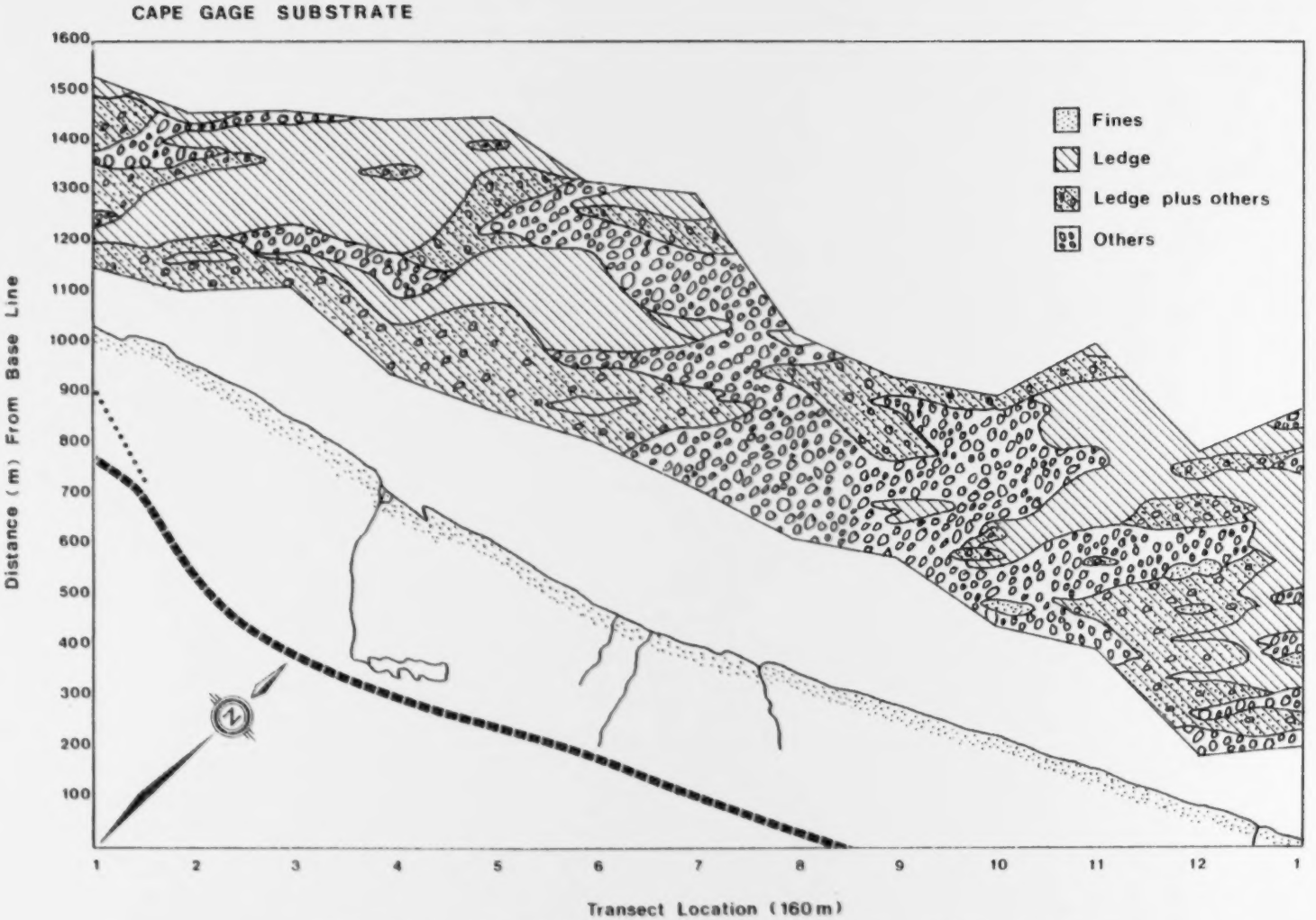

Figure 26. The distribution of fines, ledge, ledge plus others, and "others" on the Cape Gage Irish moss bed.

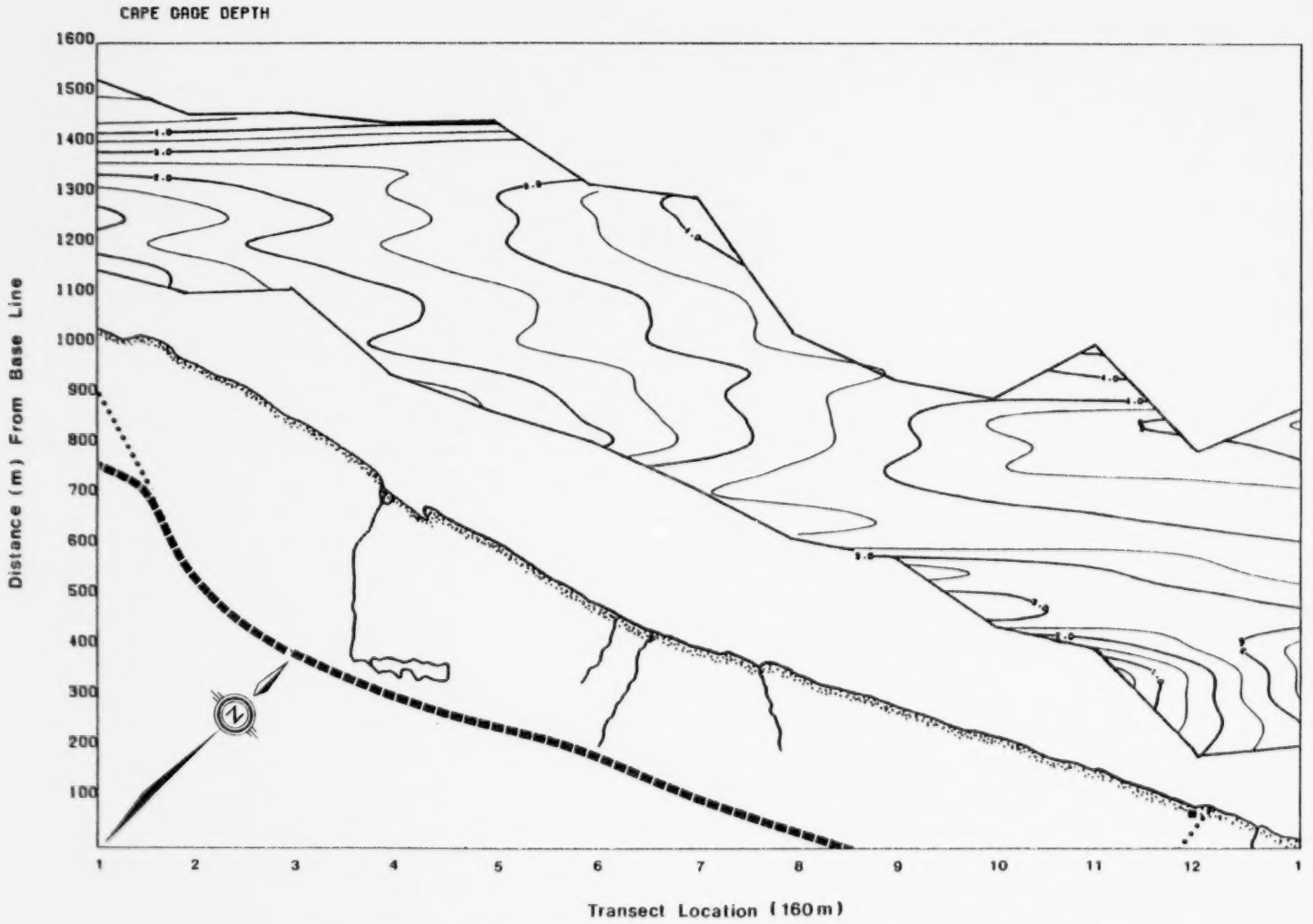

Figure 27. Depth contours (m) below chart datum on the Cape Gage Irish moss bed.

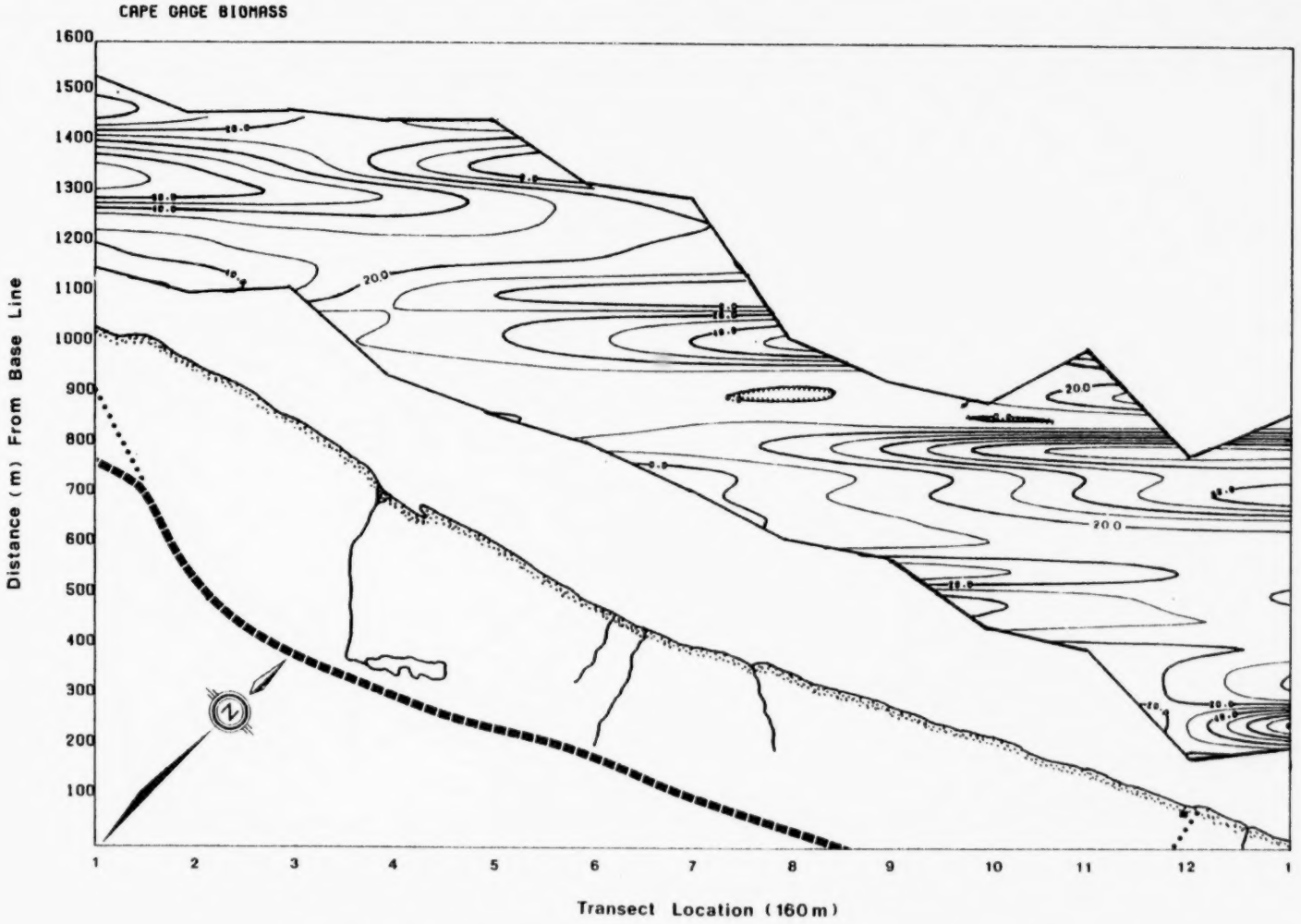

Figure 28. Biomass contours (% cover by C. crispus) on the Cape Gage Irish moss bed.

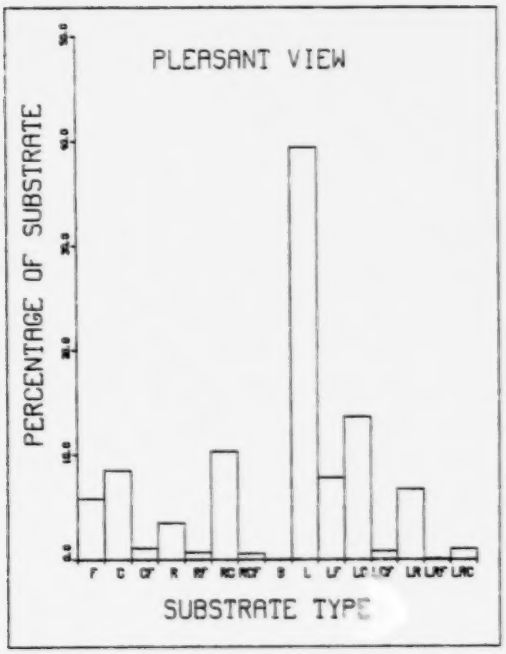

Figure 29. Percentage occurrence of each substrate type on the Pleasant View Irish moss bed (F = fines, C = cobbles, B = boulders, R = rock, and L = ledge).

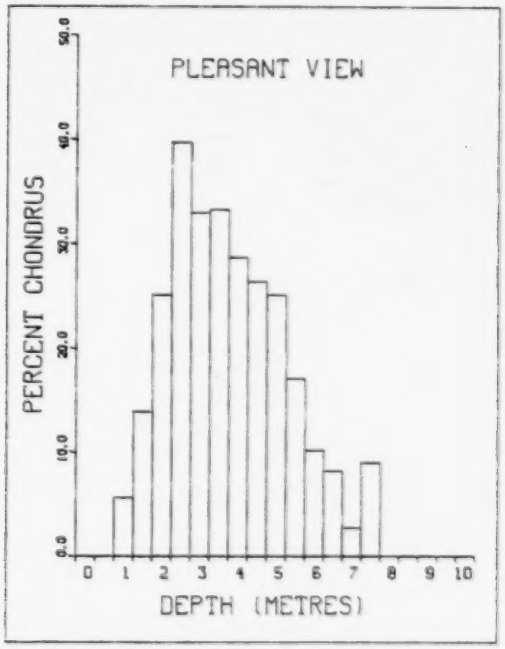

Figure 30. Percentage occurrence by C. crispus at 0.5 m depth intervals below chart datum on the Pleasant View Irish moss bed.

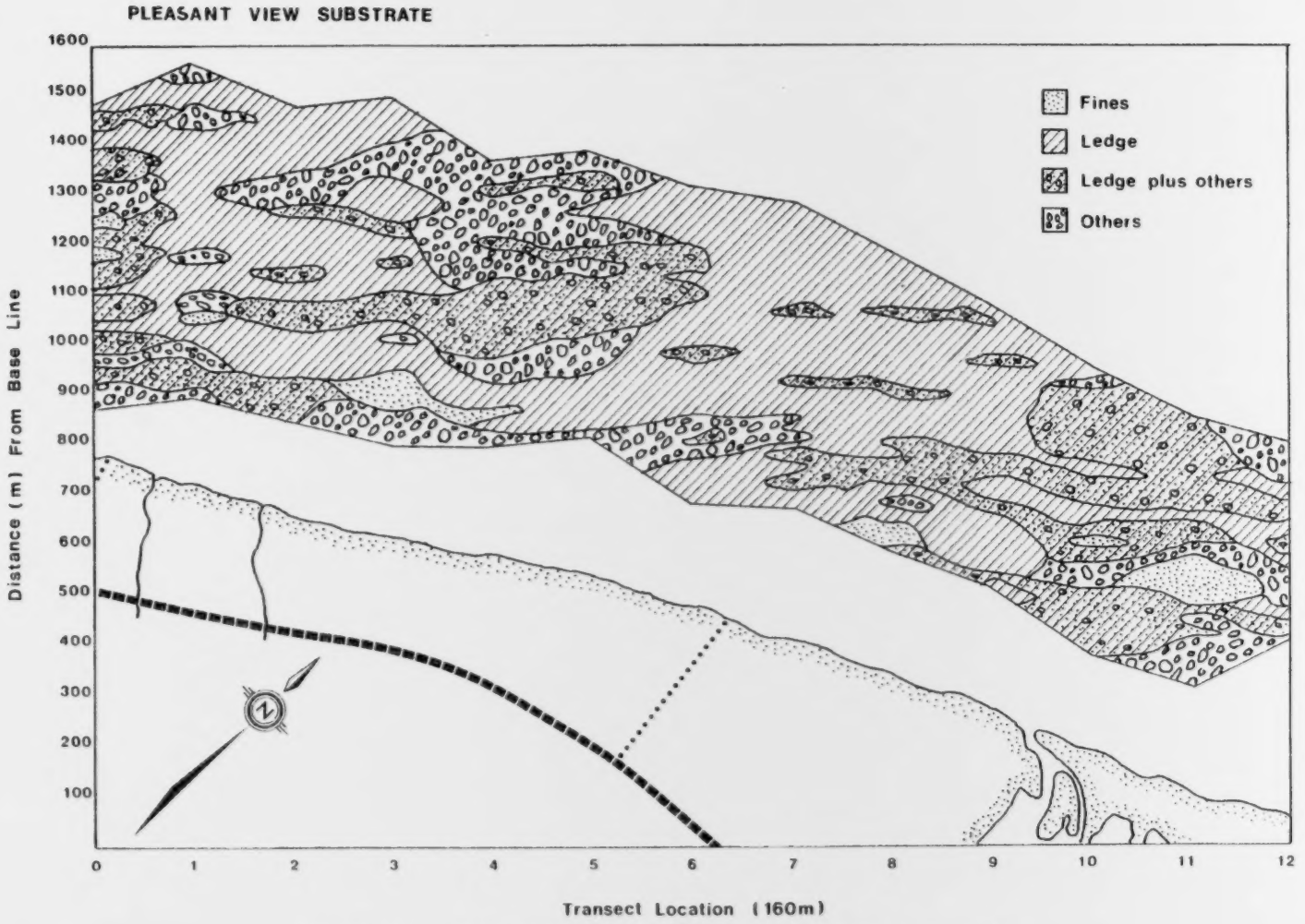

Figure 31. The distribution of fines, ledge, ledge plus others, and "others" on the Pleasant View Irish moss bed.

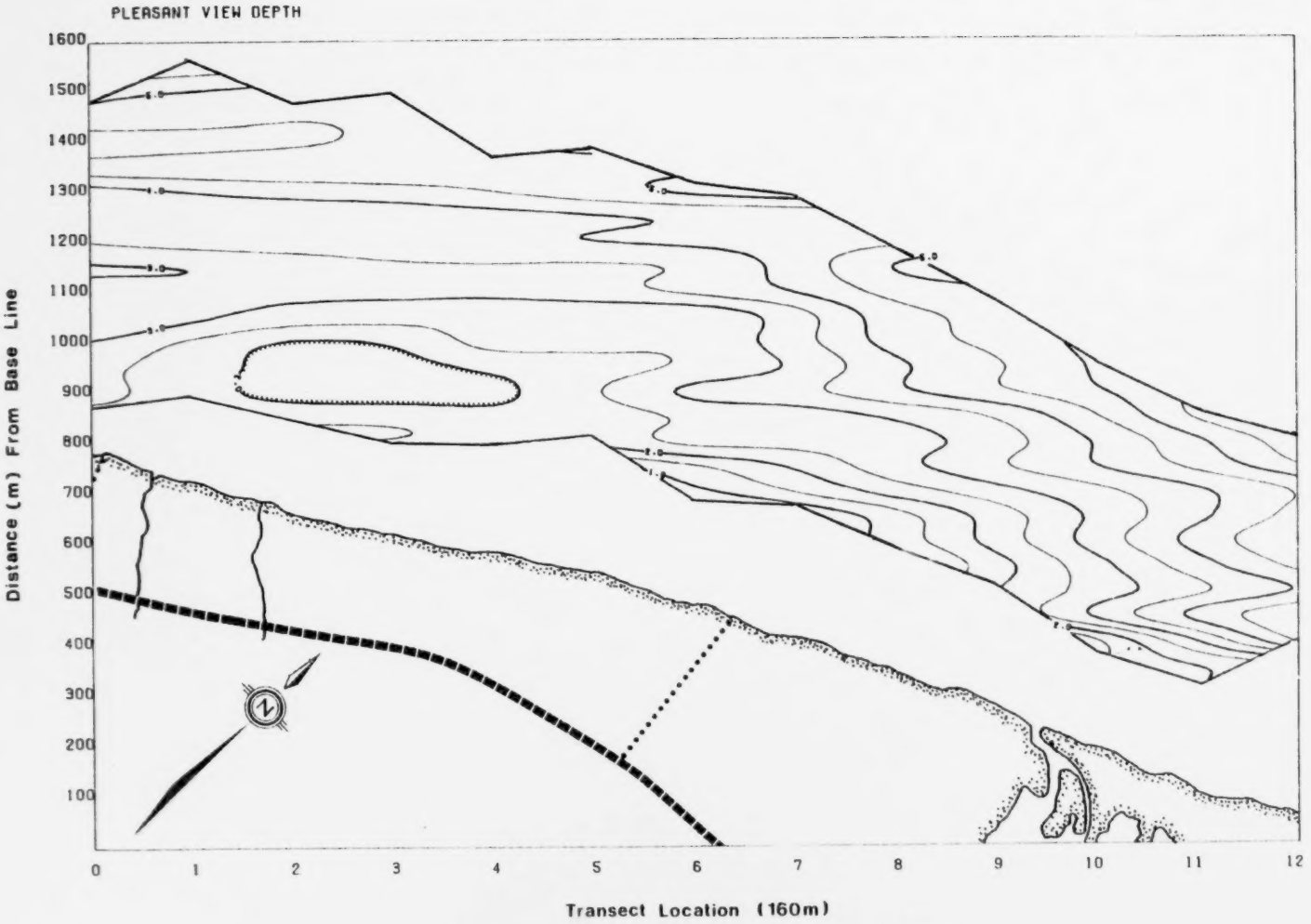

Figure 32. Depth contours (m) below chart datum on the Pleasant View Irish moss bed.

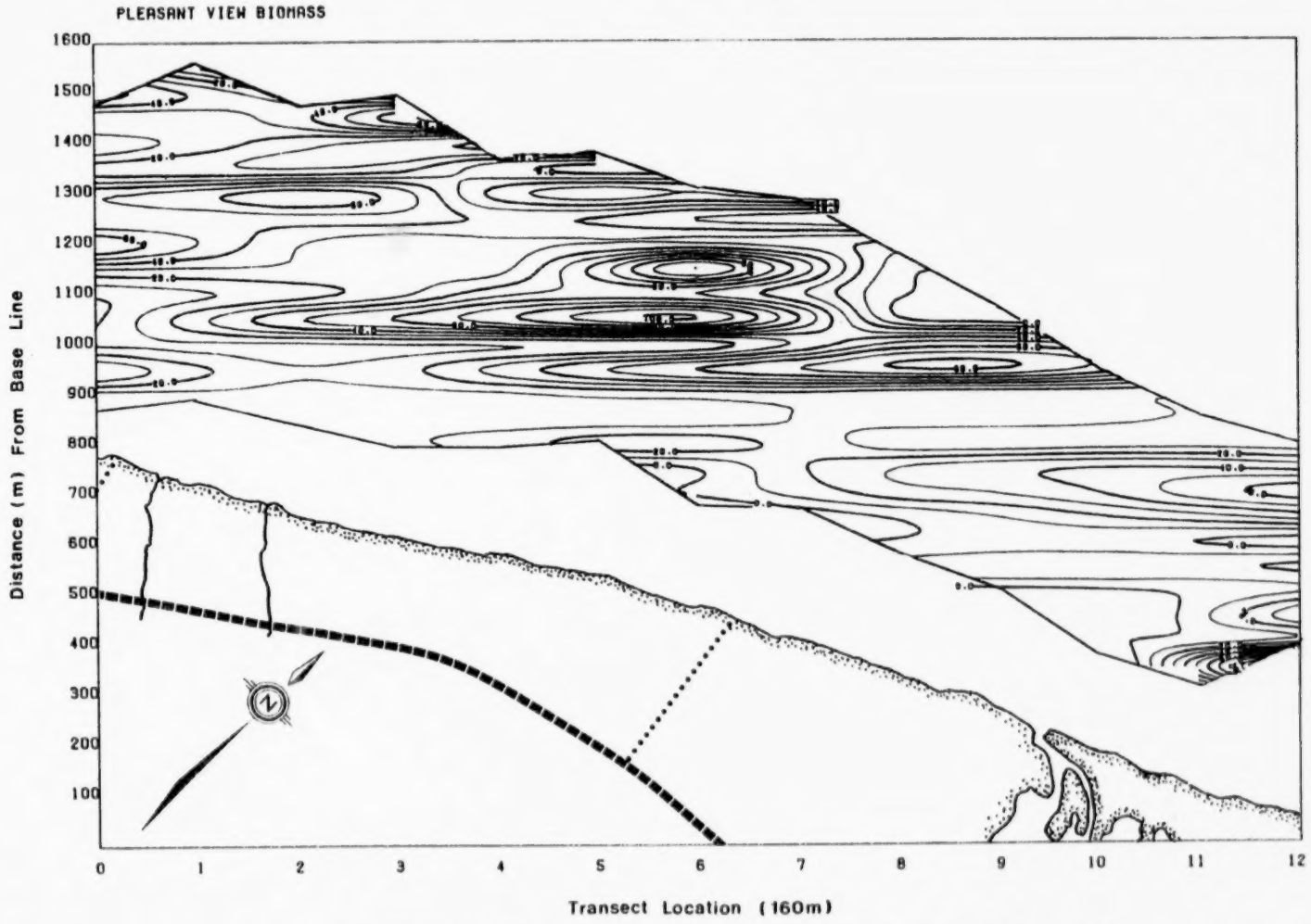

Figure 33. Biomass contours (% cover by C. crispus) on the Pleasant View Irish moss bed.

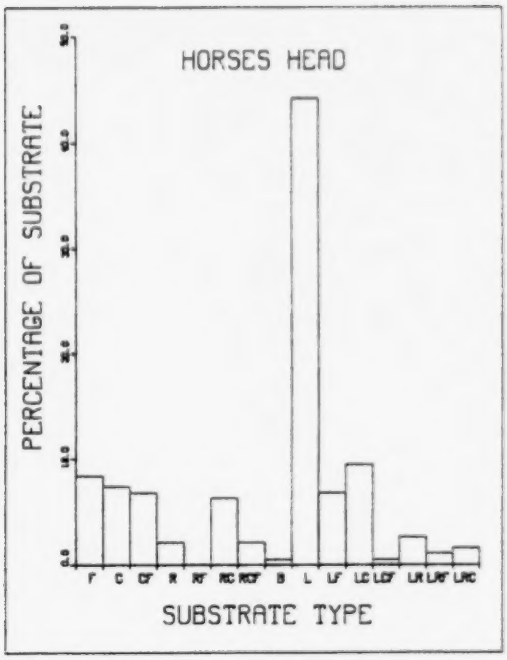

Figure 34. Percentage occurrence of each substrate type on the Horses Head Irish moss bed (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

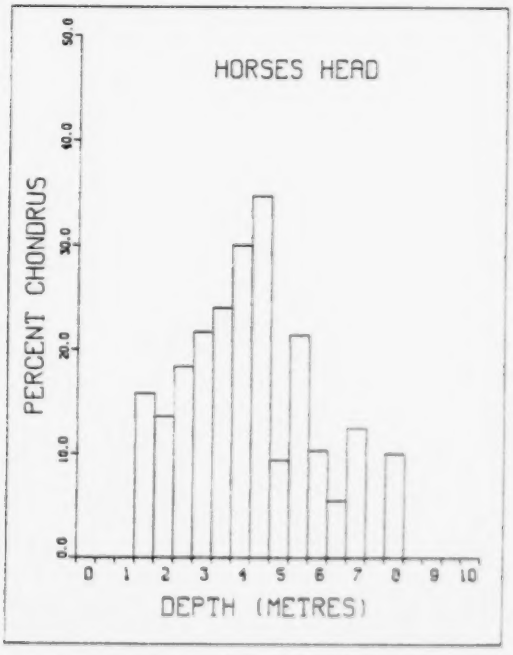

Figure 35. Percentage cover by C. crispus at 0.5 m depth intervals below chart datum on the Horses Head Irish moss bed.

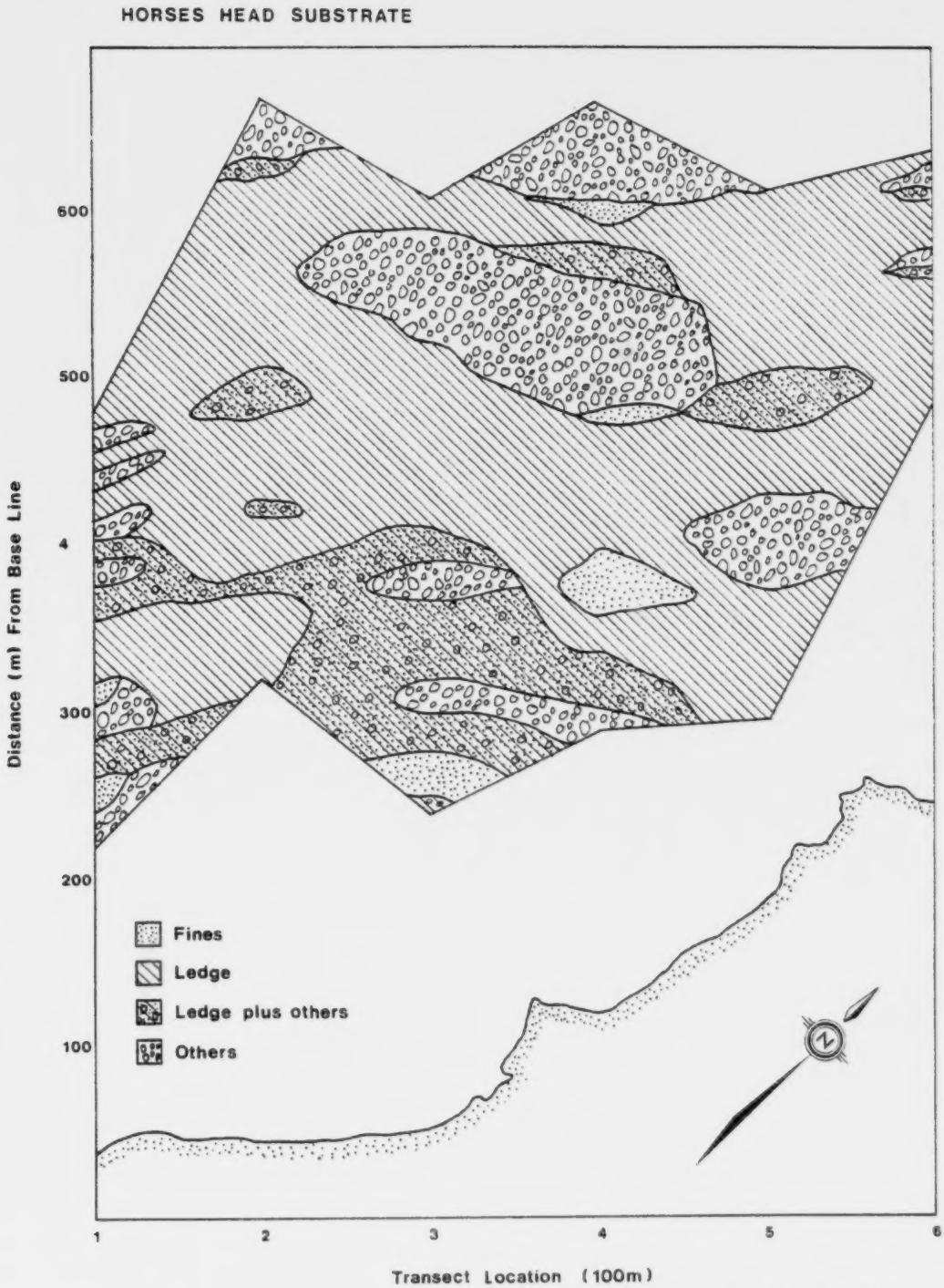

Figure 36. The distribution of fines, ledge, ledge and others, and "others" on the Horses Head Irish moss bed.

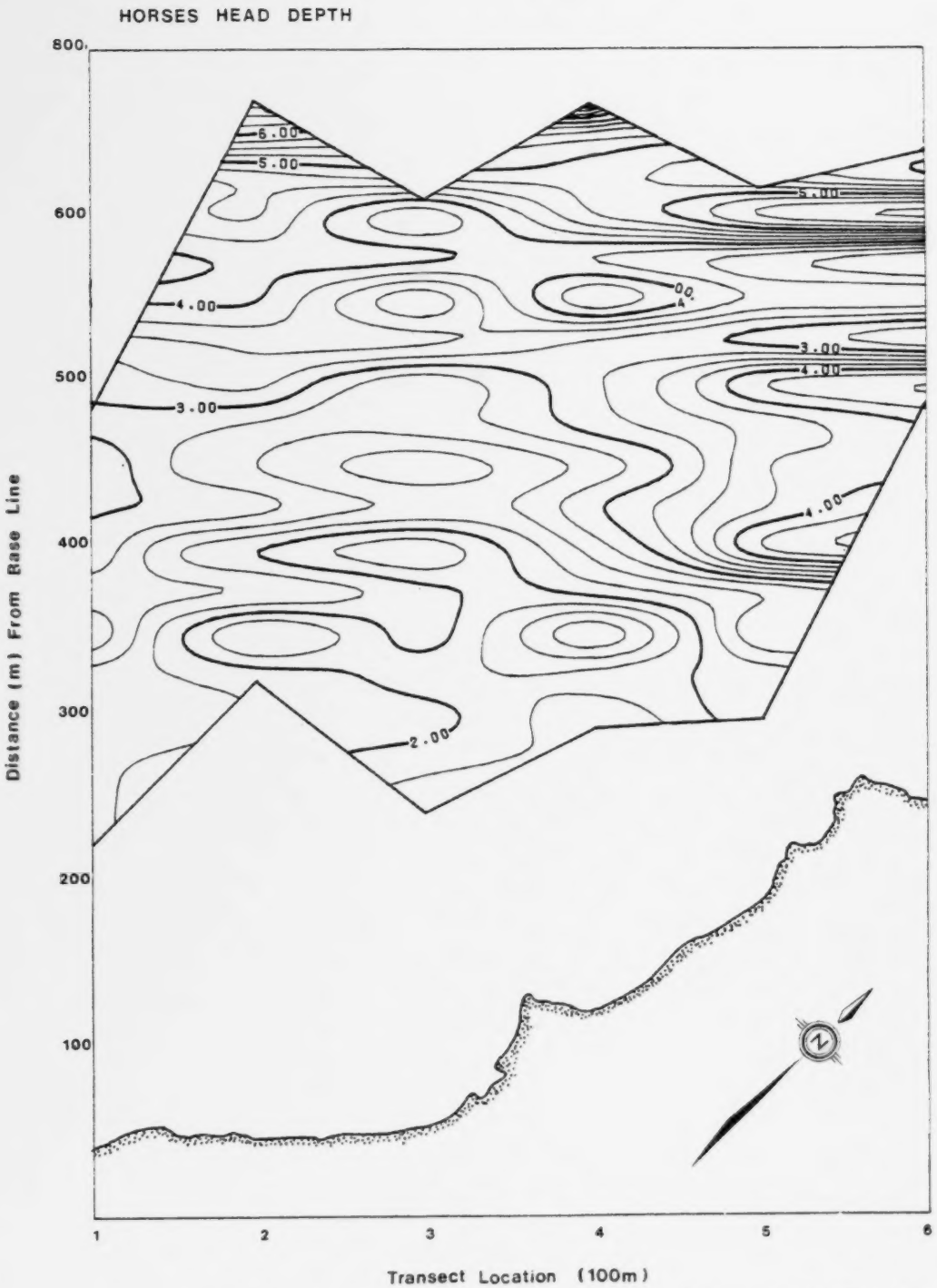

Figure 37. Depth contours (m) below chart datum on the Horses Head Irish moss bed.

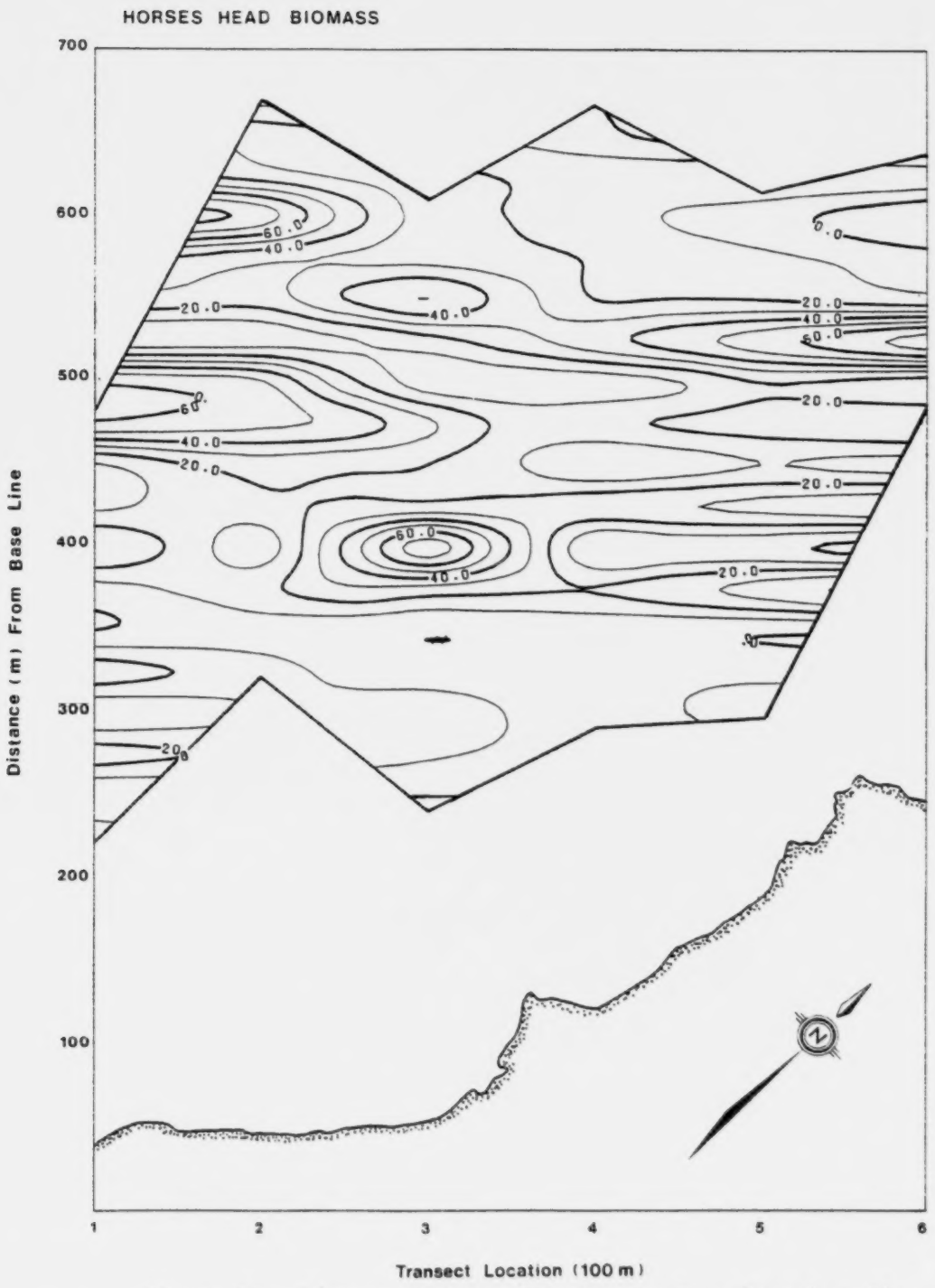

Figure 38. Biomass contours (% cover by C. crispus) on the Horses Head Irish moss bed.

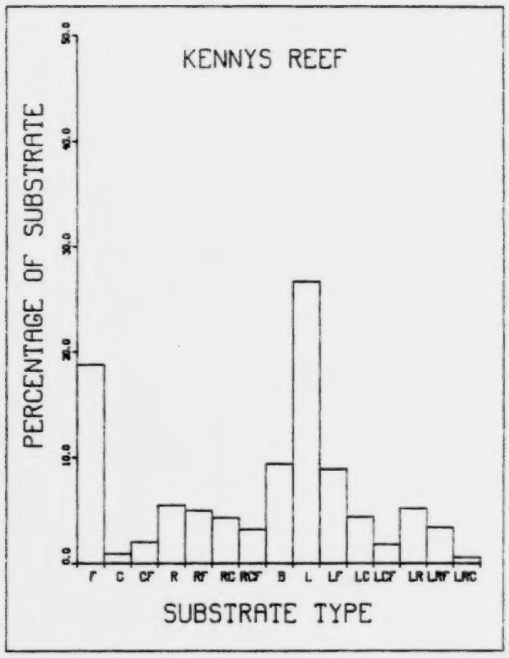

Figure 39. Percentage occurrence of each substrate type on the Kennys Reef Irish moss bed (F = fines, C = cobbles, R = rock, B = boulders, and L = ledge).

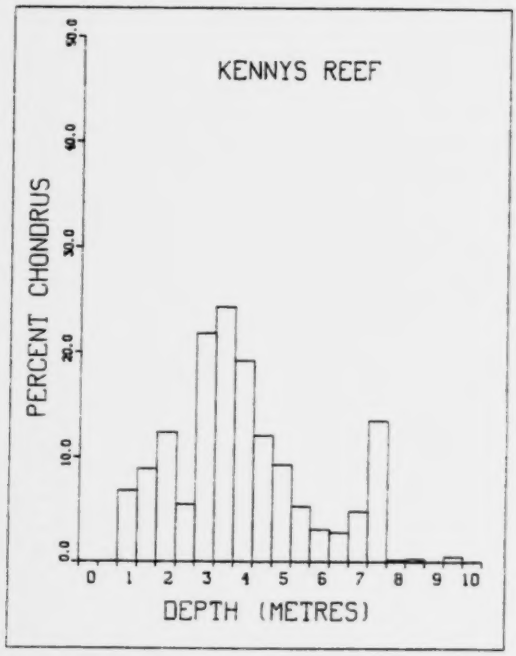

Figure 40. Percentage cover by C. crispus at 0.5 m depth intervals below chart datum on the Kennys Reef Irish moss bed.

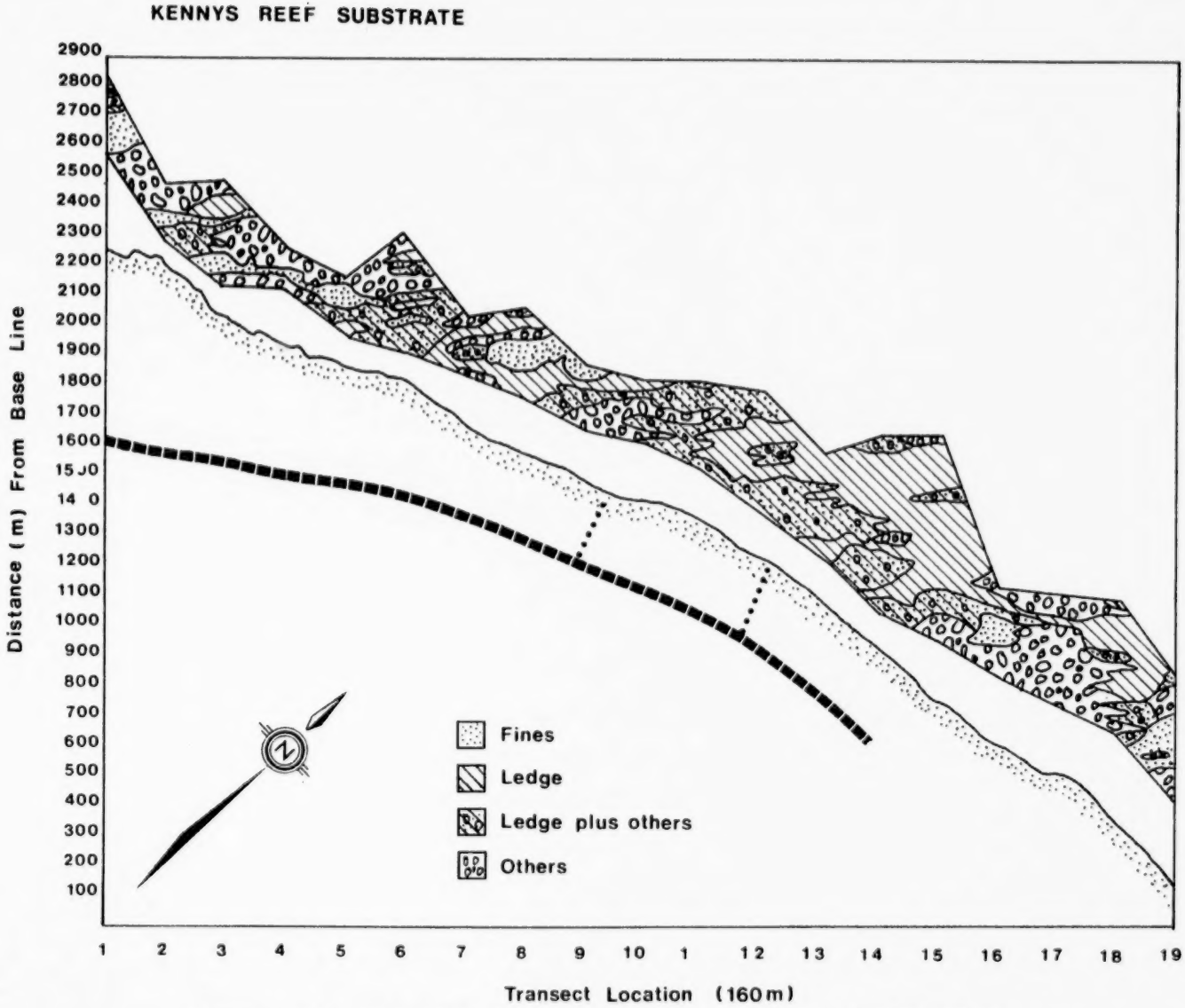

Figure 41. The distribution of fines, ledge, ledge plus others, and "others" on the Kennys Reef Irish moss bed.

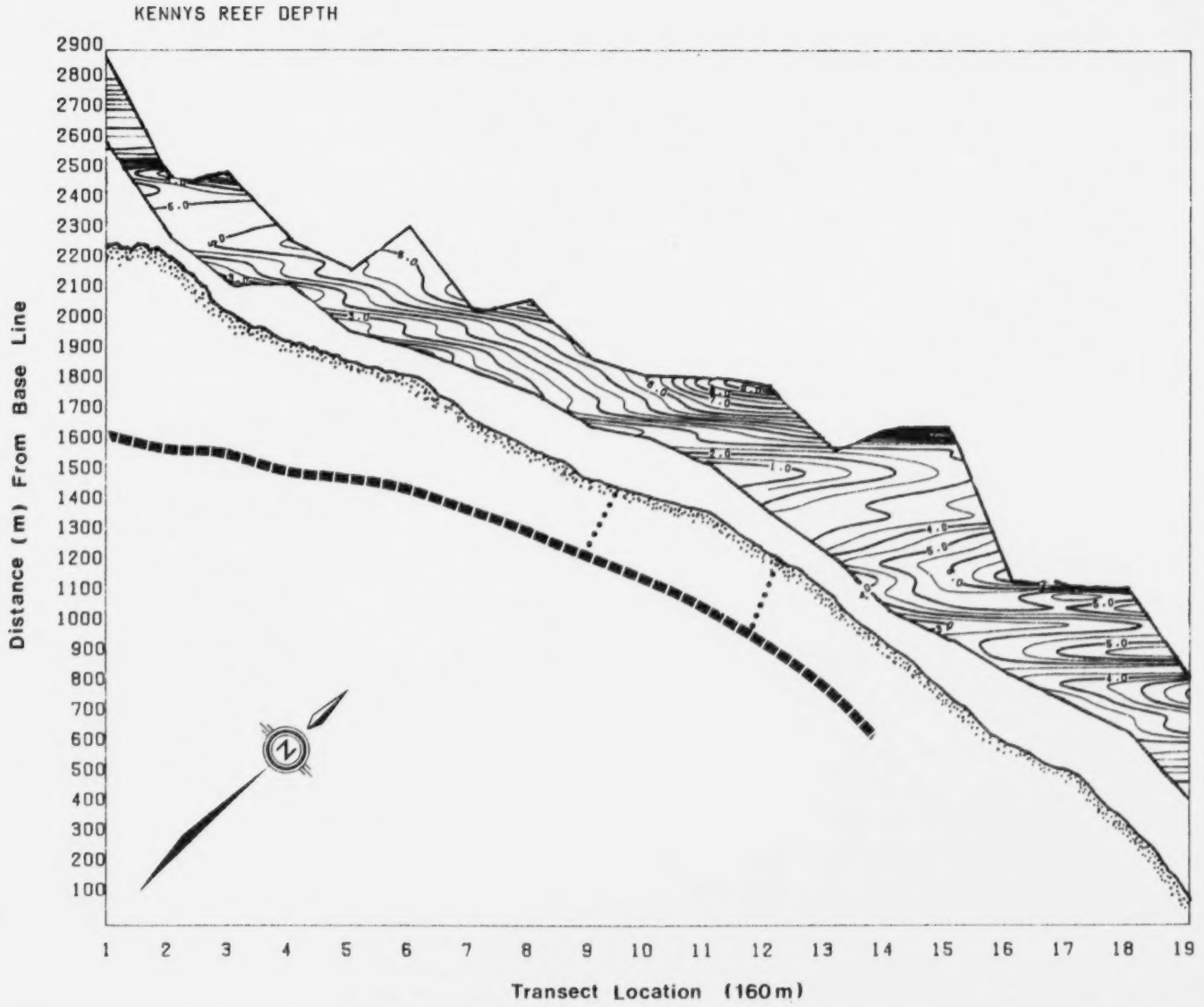

Figure 42. Depth contours (m) below chart datum on the Kennys Reef Irish moss bed.

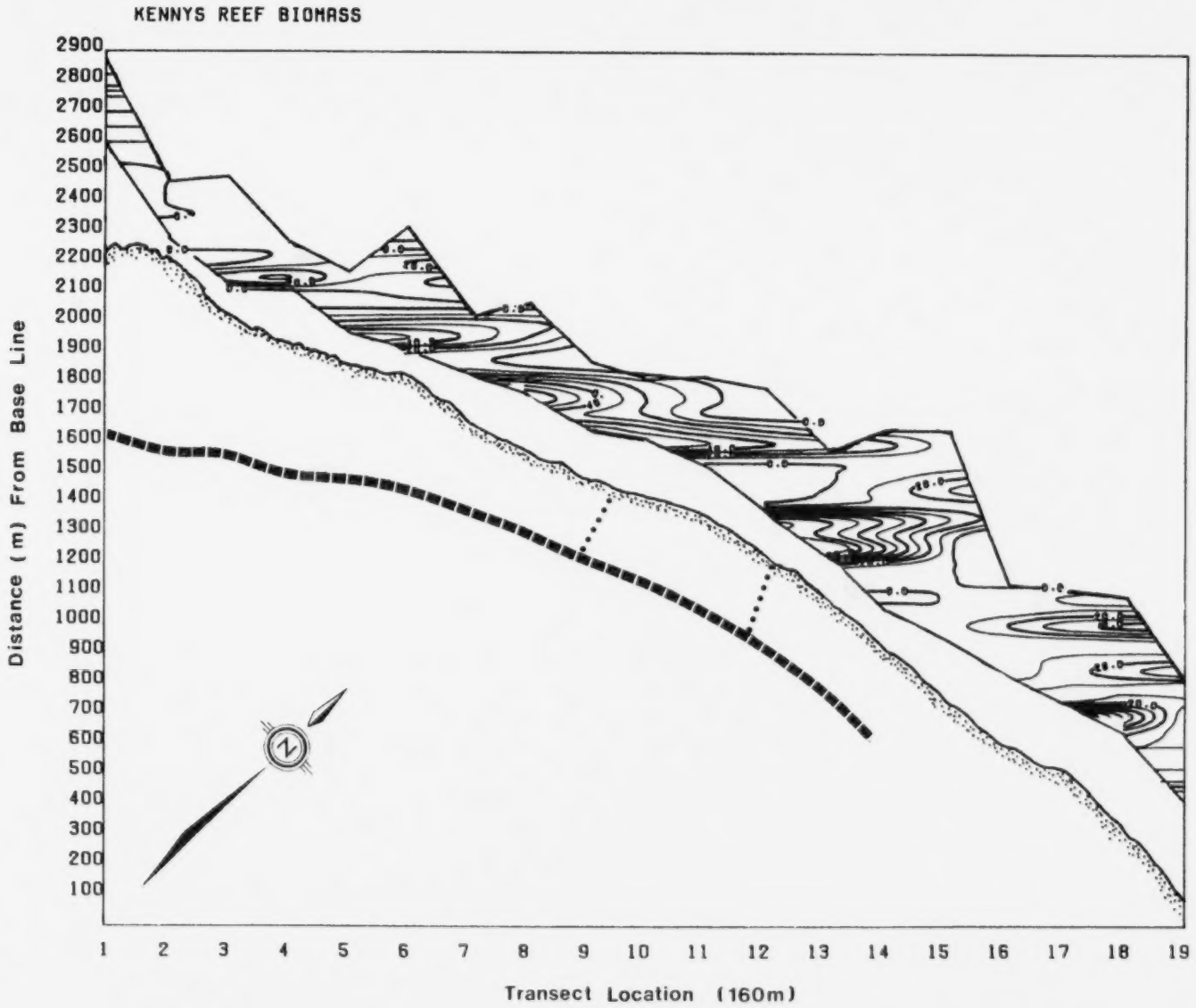

Figure 43. Biomass contours (% cover by Irish moss) on the Kennys Reef Irish moss bed.

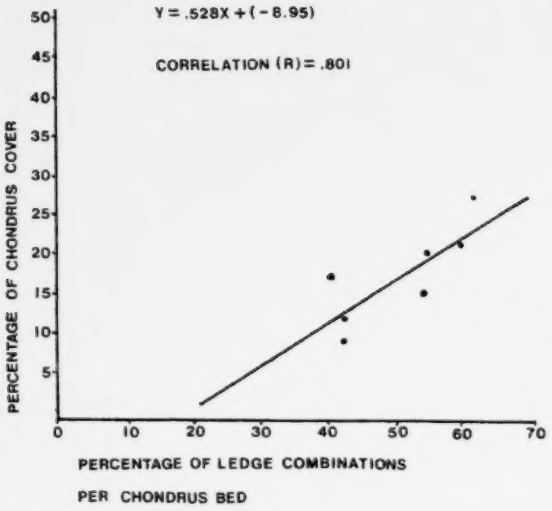

Figure 44. Linear regression fitted to percent C. crispus cover and percent ledge substrate for each major Irish moss bed in District 1.

Figure 45. An area that has been barren of C. crispus for years. It separates an area of cobbles (photo left) from Irish moss covered ledge (photo right). Photo taken in January, 1983.

APPENDIX II:

Transect data for the following beds in Marine Plant Harvesting District 1:

South Roseville, North Roseville, Miminegash Reef, Cape Gage, Pleasant View, Horses Head, and Kennys Reef

Table A. Area and percent cover of Chondrus per transect - South Roseville bed - District 1.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage Chondrus cover	Average depth (m)
1	224	90	18,400	16.2	2.7
2	229	140	38,400	16.6	3.9
3	231	340	62,400	5.8	3.6
4	233	440	72,000	11.8	3.7
5	423	460	68,800	26.8	3.3
6	197	400	60,000	20.0	2.7
7	256	350	59,200	17.3	3.3
8	129	390	57,600	28.9	2.4
9	201	330	52,800	19.9	3.2
10	174	330	49,600	34.6	3.2
11	103	290	38,400	7.5	2.6
12	112	190	29,600	17.3	1.3
13	152	180	29,600	22.7	1.2
14	102	190	21,600	17.0	1.9

...contd.

Table A. (Contd...)

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage *Chondrus* cover	Average depth (m)
15	153	80	26,400	15.7	1.6
16	185	250	24,000	5.6	3.3
17	231	50	19,200	5.3	3.0
18	205	190	23,200	7.3	2.7
19	190	100	13,600	21.6	2.6
20	406	70	17,600	8.5	2.7
21	332	150		10.4	4.5
		Total:	782,400		
				Mean *Chondrus* cover:	17.5
				Mean depth:	2.9

Table B. Area and percent cover of Chondrus per transect - North Roseville bed - District 1.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage Chondrus cover	Average depth (m)
1	158	210	34,400	13.7	2.3
2	230	220	38,400	14.0	3.3
3	282	260	37,600	11.9	2.8
4	171	210	33,600	17.1	2.4
5	152	210	45,600	22.6	2.7
6	152	360	59,200	10.5	3.5
7	138	380	66,400	21.7	2.9
8	82	450	56,000	11.5	2.5
9	204	250	39,200	28.0	2.9
10	247	240	55,200	24.2	2.4
11	130	450	70,400	20.7	2.6
12	153	430	51,200	8.0	3.5
13	199	210	32,000	9.1	2.7
14	263	190	31,200	10.6	3.8
15	266	200	29,600	8.1	3.7
16	270	170		6.8	4.1
			Total: 680,000		
				Mean Chondrus cover: 15.1	
				Mean depth: 3.0	

Table C. Area and percent cover of Chondrus per transect - Miminegash Reef.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage Chondrus cover	Average depth (m)
1	166	330	59,200	7.9	4.4
2	211	410	91,200	8.2	4.9
3	249	730	89,600	7.0	4.2
4	313	390	61,000	7.5	3.8
5	431	380	76,800	6.3	4.2
6	528	580	87,200	16.0	2.5
7	661	510	61,600	9.5	3.8
8	869	260	35,200	19.7	3.9
9	1,137	180		5.3	4.4
		Total:	562,400		
				Mean Chondrus cover:	9.7
				Mean depth:	3.9

Table D. Area and percent cover of Chondrus per transect - Cape Gage bed - District 1.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage Chondrus cover	Average depth (m)
1	125	380	58,400	14.7	2.4
2	142	350	56,800	35.3	1.6
3	257	360	68,800	33.7	2.5
4	247	500	85,600	19.1	2.3
5	253	570	86,400	14.6	2.4
6	307	510	87,200	17.1	2.9
7	304	580	78,400	20.2	3.5
8	258	400	60,000	10.0	3.3
9	290	350	64,000	4.9	3.7
10	222	450	84,000	13.4	4.3
11	233	600	96,800	29.0	3.2
12	86	610	102,400	16.7	2.8
1*	172	670		31.2	4.0
		Total:	928,800		
				Mean Chondrus cover:	20.0
				Mean depth:	2.9

*The first transect of the adjacent bed (Pleasant View).

Table E. Area and percent cover of *Chondrus* per transect - Pleasant View bed - District 1.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage *Chondrus* cover	Average depth (m)
1	172	670		31.2	4.0
			104,000		
2	187	630		31.6	3.2
			106,400		
3	189	700		23.6	3.3
			101,600		
4	224	570		26.8	3.1
			91,200		
5	277	570		28.5	3.0
			96,000		
6	205	630		35.2	2.9
			100,000		
7	263	620		38.8	2.9
			98,400		
8	235	610		25.0	3.4
			93,600		
9	243	560		21.8	3.4
			89,600		
10	209	560		16.8	3.5
			88,000		
11	218	540		18.4	3.8
			75,200		
12	378	400		26.8	4.7
		Total:	1,044,000		
				Mean *Chondrus* cover:	27.3
				Mean depth:	3.4

Table F. Area and percent cover of Chondrus per transect - Horses Head bed - District 1.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage Chondrus cover	Average depth (m)
1	179	260	30,500	18.7	2.7
2	276	350	36,000	30.8	3.4
3	189	370	37,500	23.4	2.4
4	170	380	35,000	14.4	3.5
5	110	320	24,000	24.3	3.9
6	234	160		16.2	3.1
		Total:	163,000		
				Mean Chondrus cover:	21.8
				Mean depth:	3.2

Table G. Area and percent cover of Chondrus per transect - Kennys Reef - District 1.

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage Chondrus cover	Average depth (m)
1	320	280	36,800	5.4	4.6
2	80	180	42,400	4.7	4.9
3	100	350	40,000	1.8	4.5
4	190	150	27,200	9.1	5.2
5	110	190	46,400	0.2	4.3
6	80	390	47,200	8.3	4.7
7	151	200	40,000	22.8	3.3
8	213	300	41,600	12.0	5.1
9	189	220	36,000	24.8	4.2
10	184	230	42,400	12.8	4.3
11	150	300	56,000	11.3	5.1
12	162	400	60,800	14.9	2.8
13	141	360	76,800	6.8	2.9
14	127	600	103,200	27.7	3.3

...contd.

Table G. (Contd...)

Transect no.	Distance from shore to inner bed (m)	Width of bed (m)	Calculated area (m^2)	Percentage *Chondrus* cover	Average depth (m)
15	211	690		10.9	4.2
			80,000		
16	248	310		6.5	4.8
			55,200		
17	230	380		12.8	4.2
			65,600		
18	334	440		20.2	4.1
			66,400		
19	337	390		11.9	4.1
		Total:	964,000		
				Mean *Chondrus* cover:	12.6
				Mean depth:	4.1